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In Phase I the effects of cold air (c), water (w), fatigue (f), and exercise (e) on physiological and psychological performance, and the effectiveness of several techniques for the suppression of shivering wereinvestigated in 15 male subjects. Cold exposure was determined to be the most significant factor in reducing performance, causing significant reductions ($p \leq 0.05$) in skin and rectal temperatures, temperature perceptions, shooting performance, grip strength, and dexterity both alone or when combined with any or allother factors. Cognitive performance, however was highest in the c/w/e/f, control, and c conditions, with theoverall scores in the c/w, c/w/f and c/w/e conditions significantly lower than control and c/w/e/f. Shivering gradually increased throughout exposure in cold conditions but was delayed in conditions which included exercise. Rectal temperatures increased during exercise, but later fell to the same level as in the non-exercise conditions. After 2+ hours of exposure 4 shiver-suppression techniques were applied: voluntary relaxation (R), breath holding (B), mental arithmetic (M), and warm water ingestion (W). Shivering was significantly suppressed by R, B, and M.In Phase II analysis of evoked potentials and reaction times during central and peripheral cooling indicated that cooling methods have differing effects on physiological and physical function.

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Reaction time and evoked potentials during moderate internal and external cooling. DJ Israel, RG Hoffman, and LE Wittmers. Paper presented at the American Physiological Society and American College of Sports Medicine Conference, Sept 23-26, 1992.

The effect of shiver suppression on core temperature in cold stressed man. LE Wittmers, RG Hoffman, and D Israel. Paper presented at the 76th Annual Meeting of the Federation of American Societies for Experimental Biology, April 9, 1992, Anaheim, CA.

Temperature perception, motor skills, and voluntary suppression of shivering during cold stress. CJ Gebeck, LE Wittmers Jr, DJ Israel, and RG Hoffman. Paper presented at the NIH-MBRS-MARC Symposium, October 11-13, 1990, Nashville, Tennessee.

Voluntary suppression of cold air induced shiver in humans. LE Wittmers, Jr., RG Hoffman, and D Israel. Paper presented at the 74th Annual Meeting of the Federation of American Societies for Experimental Biology, April 4, 1990, Washington, D.C.

The role of light exercise on the onset and intensity of shivering in cold exposed humans. Wittmers, L., Israel, D., and Hoffman, R. Paper presented at the 41st Annual Fall Meeting of the American Physiological Society, October 6-10, 1990, Orland, Florida

Thermal sensation and motor skills following prolonged cold stress. RG Hoffman and LE Wittmers, Jr. Paper presented at the 74th Annual Meeting of the Federation of American Societies for Experimental Biology, April 4, 1990, Washington, D.C.

Phase I

CONTRACT NO.:	N00014-88-K-0582
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Introduction

Naval personnel are often exposed to the environmental stress of cold water and/or cold air in conjunction with exercise associated with the performance of their duties. While exposed to these environmental stressors, personnel are required to make decisions relative to previous orders and present tactical conditions, and then execute them quickly and accurately. This study was designed to address the paucity of information, from a physiological and psychological perspective, concerning human performance under these adverse conditions.

Exposure to cold has several debilitating effects. These include loss of manual dexterity due to shivering and peripheral cooling of the hands and feet, and reduction of cognitive abilities, especially for more complex tasks (1).

Shivering is one of the most common physiological reactions to cold stress. The occurrence of shivering is often demoralizing to military personnel and may interfere with the smooth execution of various motor tasks. The major physiological function of shivering is to increase heat production to maintain core temperature. Unfortunately, this thermal generating reflex also results in whole body tonic and clonic-like muscle activity which may impair motor performance. Past studies in our laboratory have concentrated on the mechanisms of initiation and control of shivering. With a better understanding of how shivering is controlled, perhaps methods could be developed to alter the detrimental effects of shivering, while minimizing loss of the beneficial heat generated by shivering.

During cold exposure, activation of peripheral cold receptors and central thermosensitive structures generates afferent inputs to thermoregulatory centers. In mammals the hypothalamus contains the primary thermoregulatory center, but subhypothalamic areas of the brainstem and spinal cord are also capable of transforming thermal input signals to efferent signals controlling thermoregulatory effector systems (1). Activation of these centers initiates and maintains the efferent neuronal signals which increase muscle activity to produce heat and modify posture to reduce heat loss (2,3). As a cold stimulus increases, this activity progresses from increased muscle tone without visible tremor (pre-shivering tone) to visible shivering, which is characterized by bursts of tremor (2). Fully developed shivering exhibits a species-specific rhythm resulting from the grouped discharge of motor units (4). It is likely that the grouped discharges are generated at the level of the spinal cord since these types of group discharges have not been observed in the descending supraspinal drive signal for shivering (5), and because shivering can be elicited even in chronically spinalized dogs and rabbits by cooling of the spinal cord (6). Thus it appears that shivering is initiated and modulated in both central and spinal centers.

The overt oscillations of shivering in response to a cold stress begin as early as two minutes after exposure to cold air, and become generalized by 10-24 minutes (7, 8), with an increase in oxygen consumption up to 3-4 times basal levels after fifteen minutes of cold exposure (6, 9).

Although shivering is considered an involuntary response, like respiration, it can be inhibited temporarily (2). Glaser et al.(10) noted that at low intensities shivering can be temporarily suppressed by voluntary relaxation and cessation of breathing. Glickman et al.(11, 12) reported that even after 4 hours of exposure to -29.9°C air, their subjects were able to effectively suppress shivering by relaxing.

In addition to relaxation, shivering can be suppressed by a number of other non-thermoregulatory mechanisms. Martin and Cooper (13), and Klenow et al. (14) noted that shivering, as measured by electromyographic (EMG) activity, consistently decreased during a mental arithmetic task, while isometric muscle contractions resulted in variable effects. Other non-thermal sensory stimuli that are known to suppress the shivering response in mammals include mechanical pressure on the eyeball, mechanical pressure on the skin (5,6), stretching a muscle (2), and electrical cutaneous nerve stimulation with a rate less than 50 Hz (6). Cardiovascular and respiratory reflexes also modulate the shivering response. Low carotid sinus pressure (15), lung inflation (16), hypoxia (17), and hypercapnia (18) have been demonstrated to inhibit shivering. In contrast, noxious stimuli such as twisting the pinna (7), pin pricks, blowing on the hair of the back, and electrical cutaneous nerve stimulation at a rate greater than 50 Hz have been reported to increase shivering intensity (6).

As would be expected, thermal stimuli have been shown to have an effect on shivering intensity. For example, cooling of the respiratory tract during cold exposure stimulates shivering by increasing afferent input from esophageal cold receptors (19), and application of radiant heat to the face decreases EMG activity of the biceps brachii, trapezius, and rectus femoris in subjects exposed to -3°C air for 1 hour (12).

The muscle tension and tremor of shivering may impede performance in individuals who must undertake tasks that involve motor speed and accuracy under cold stress. Outdoor sportsmen, commuters caught unaware of severe weather conditions, or military personnel who must perform their operations under extreme weather conditions are just a few examples of critical situations when loss of fine motor control or motor speed could prove disastrous. Temporary suppression of shivering during fine motor tasks may be one way to improve performance during cold exposure. Indeed some shiver suppression techniques may be currently in use. For example, breath holding while shooting is a standard marksmanship technique, and mental concentration on a task may unconsciously inhibit shivering. Hemingway (2) suggested that some suppression of shivering takes place whenever a voluntary movement is initiated.

Despite these references to the ability of man to suppress shivering, there have been few attempts to quantify the relative effectiveness of methods of shiver suppression or correlate this suppression with changes in electromyographic activity (14,13). In Phase I of this study, four shiver suppression techniques were assessed to determine which of these techniques would be the most effective in reducing the intensity of shivering in humans.

In addition to the question of suppression of shivering, there have been, to our knowledge, no studies that investigate the possible augmenting effect of the combination of fatigue (sleep deprivation) and exercise on the expression of shivering. Navy personnel on maneuvers are frequently stressed by cold air and cold water as well as by sleep deprivation and/or exercise, and are required to think clearly and have good motor control and weapons accuracy. Studies dealing with theses parameters are not only needed but essential for the safety of personnel and the successful completion of their missions.

Several investigations have addressed the effects of cold exposure alone on cognitive performance. The effects of cold on cognitive function depends on the length and difficulty of the task involved. Ellis, (20) and Teichner (21) reported that response times during simple and serial choice reaction time tasks are unchanged when subjects are exposed to cold air. Ellis (22) and Enander (23), found faster responses to more complex reaction time tasks involving a brief delay or multiple choice. The number of mistakes made by subjects during the latter, more complex tasks was also significantly increased during cold exposure. There appears to be no improvement in performance with additional sessions of cold exposure, since repeated moderate cold exposures (5°C) had no effect on a complex conditional discrimination task (24).

The present study addresses shiver expression and voluntary shiver suppression following cold air/cold water exposure, with and without exercise and/or fatigue. The initial phase of this project also examined the effect of these stressors on combat relevant psychomotor performance including rifle shooting performance (rate of fire, accuracy and judgmental shooting) and performance on a selected battery of command and control relevant cognitive tasks.

Materials and Methods

Subjects:

Male volunteers, 21 to 35 years old, were recruited from the 148th Fighter Interceptor Group of the Minnesota Air National Guard in Duluth, Minnesota, the St. Louis County Sheriff's Department S.W.A.T. Team, local reserve units and former military personnel. Potential subjects were recruited from the aforementioned groups because it was deemed necessary that they be qualified in the use of firearms (AR15-2 or equivalent, and Smith & Wesson .357 revolver or equivalent) prior to participation. It was felt that this would minimize any training or learning effect that might occur during the course of the experiments. Each potential subject was informed as to the general purpose, procedure, and possible risks of the experiments and gave his written consent prior to any further screening. A copy of the informed consent document is included as Appendix I. Protocols for this project had been approved jointly by the University of Minnesota Committee for the Use of Human Subjects in Research and the United States Navy prior to any recruitment. Anthropomorphic data for the final subject pool is contained in Table 1.

Table 1. Subject Anthropomorphic Data

Subject #	*Height (cm)*	*Weight (kg)*	*Age (yrs)*	*% Body Fat*	*Resting Heart Rate (bpm)*	*Stress Test Heart Rate (bpm)*	*Systolic BP (mmHg)*	*Diastolic BP (mmHg)*
1	178	77.9	35	16.5	76	165	128	74
3	173	58.6	24	8.5	60	176	116	64
4	175	64.1	21	10.7	60	125	110	62
5	173	76.8	21	16.4	68	160	112	62
6	188	83.9	27	21.1	72	165	118	70
8	183	95.4	34	22.4	80	165	134	76
9	180	88.2	21	19.9	68	178	124	72
10	175	64.1	21	12.9	68	140	112	72
11	175	65.9	27	18.6	44	140	114	64
12	183	90.9	33	22.9	80	174	120	64
13	190	80.0	27	19.4	62	150	132	70
14	178	75.9	26	18.5	76	170	116	72
15	183	88.6	30	19.9	88	175	136	72
Mean	179.5	77.72	26.6	17.50	69.4	160.2	120.9	68.8

Note: Subjects number 2 and 7 withdrew after 2 experiments citing discomfort involved with the experiments. Data from these experiments were not used in any of the analyses.

Volunteer Selection and Screening:

Volunteers were initially screened with a brief medical history and a 12-lead electrocardiogram (ECG) which was interpreted by a physician from the Department of Clinical Sciences, University of Minnesota Duluth School of Medicine. Percent body fat was estimated by hydrostatic weighing and calculated using the method developed by Brozek (25). Volunteers with normal ECG's, body fats less than 25%, no pre-existing medical conditions, and using no prescription medications were accepted for further screening.

Volunteers then underwent a treadmill exercise test, employing a modified Balke protocol (26). This involved walking on a treadmill at a speed of 3 mph starting at a 2% grade. The grade was increased by 2%, every two minutes, to a maximum of 18% grade. Blood pressure and heart rate were recorded during the last 30 seconds at each grade. Any volunteer was disqualified from further participation in the study if their heart rate exceeded 90% of their age predicted maximum (APM = 0.9 x [220-age]), a systolic blood pressure that exceeded 200 mmHg, or diastolic blood pressure that exceeded 100 mmHg at or before reaching the 18% grade.

Subjects who passed all of the above screening criteria were familiarized with the laboratory and experimental protocols prior to participation in any experimental protocols. This orientation included instruction and practice in use of the devices to be employed for evaluating motor skill performance, as well as information about procedures for collecting physiological data (electrode hookup, temperature sensor placement and sequence of the experiment). Upon completion of the orientation, subjects were scheduled for their first experiment and given the Cold Stress Subject Instruction Sheet which provided instructions for eating, sleeping, and drinking behavior expected of them the day prior to each experiment (see Appendix I).

Experimental Conditions:

All experiments were conducted in a 130 square foot, thermostatically controlled (±1.0°C), environmental chamber. A combination of five environmental or physiological parameters were used to produce a set of 6 conditions as listed below.

Experimental conditions:

Condition 1. Cold

Condition 2. Cold/wet

Condition 3. Cold/wet/sleep deprivation

Condition 4. Cold/wet/exercise

Condition 5. Cold/wet/sleep deprivation/exercise

Condition 6. Warm

Condition parameter definitions:

Cold............................ Chamber temperature set to 0°C.

Warm .... Chamber temperature set to 21.0°C.

Wet............................. Subjects were periodically required to stand 3-5 seconds in a 1/2 barrel filled to the 15" mark with 10° C water.

Sleep deprivation (fatigue) .... Subjects were deprived of sleep for 24 hours prior to the beginning of their experiment.

Exercise....................... During the first hour of cold exposure subjects were required to exercise for two 12 minute periods on a stepping ergometer at a work level sufficient to increase their heart rate to 70% of their age predicted maximum heart rate.

Each subject participated in the following six experimental conditions presented in a counterbalanced order (see Table 2).

Table 2. Counterbalance Design
(test order for each subject)

Subject	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
1	warm	c/w	cold	c/w/e/f	c/w/e	c/w/f
3	c/w/e	c/w/e/f	warm	c/w/f	c/w	cold
4	c/w/e/f	c/w/f	c/w/e	warm	cold	c/w
5	c/w/f	cold	c/w/e/f	c/w	warm	c/w/e
6	c/w/f	c/w/e	c/w/e/f	cold	c/w	warm
8	c/w	warm	c/w/e	c/w/f	cold	c/w/e/f
9	cold	c/w/e/f	warm	c/w/f	c/w	c/w/e
10	c/w/f	c/w	c/w/e/f	warm	c/w/e	cold
11	c/w/e	c/w	cold	c/w/f	warm	c/w/e/f
12	c/w/e	c/w/f	warm	c/w/e/f	cold	c/w
13	warm	c/w/e/f	c/w	c/w/f	c/w/e	cold
14	c/w	warm	cold	c/w/e	c/w/e/f	c/w/f
15	c/w/e/f	cold	c/w	c/w/f	c/w/e	warm

Key: c: cold w: wet
e: exercise f: fatigued

Protocol:

Upon arrival for each experiment, subjects were instrumented and dressed as detailed below before entering the experimental chamber. The first hour of each experiment consisted of exposure to the assigned condition (e.g. cold/wet/exercise). The subsequent 75 minutes were occupied by performance evaluations (shooting, cognitive function, dexterity, etc.), with the final 15 minutes spent evaluating shiver suppression techniques. Individual methods for evaluating performance as well as a detailed description of the protocol follow.

Preparation:

Following instrumentation as described below, the subject dressed in military type fatigue pants, shirt and combat boots (the subject wore his own socks and underwear). Leads from the ECG, surface electromyograms (EMG), and temperature sites were attached to harnesses on a web belt. The subject could then move about freely without interference from the 31 leads. Prior to entering the environmental chamber, control (baseline) values for temperatures, hand grip strength, temperature perceptions, and comfort perceptions were collected.

The subject entered the chamber with a technician where the EMG and temperature harnesses were interfaced to their respective systems. The subject was then seated on a backless stool and data collection was initiated. The first hour of the experiment consisted of exposure to the stressors assigned to that condition, (see Table 2) (refer to Gantt charts, Appendix I, for a graphical depiction of the following information) During wet protocols, the subject was instructed to step into and out of the water every twelve minutes. For the exercise protocols, the subject was instructed to exercise at the twelve and thirty-six minute mark. Exercise bouts lasted for twelve minutes on a stepping ergometer. The work load was adjusted by increasing or decreasing the climbing rate to maintain the subject's heart rate at 70% (+/- 10 beats/minute) of his age predicted maximum heart rate. Heart rate was monitored with a wireless heart rate monitor (CIC Heart Watch, Hempstead, NY) providing visual and auditory feedback to the subject. Respiratory and cardiovascular parameters were measured every twelve minutes during the first hour of each experiment, starting nine minutes from the start.

The second hour of the experiment consisted of performance evaluation involving the following procedures detailed below: Complex Cognitive Assessment Battery (CCAB), FireArms Training System (F.A.T.S.) simulations, dexterity tests, and grip strength. Collection of physiological data, including temperaatures, metabolic data (carbon dioxide production, respiratory rate, heart rate), blood pressure, and EMGs continued throughout the experiment. In conditions including the wet stressor, subjects were required to step into the water during transitions from F.A.T.S. to CCAB tests.

The final 15 minutes of each experiment were used to evaluate the four shiver suppression techniques (warm water, relaxation, breath hold, mental task). Subjects were instructed to stand and refrain from any voluntary movements during this time as shivering was monitored by EMG activity. Subjects performed the 4 shiver suppression techniques in counterbalanced order. Each shiver suppression technique was preceded by two minutes of normal shivering to allow shivering to return to baseline levels after the previous technique and to provide control EMG data.

Tests were administered in the following time sequence (± 5 minutes) with times from the start of the experiment (For details of each condition see Gantt charts in Appendix I).

-2 min	Grip Strength	
-1 min	Temperature & Comfort Perceptions	
0 min	Start of exposure (cold or warm)	
0 min	Temperature & Comfort Perceptions	
1 min	Metabolic Rate: HR, BP, EMG	
60 min	Temperature & Comfort Perceptions	
61 min	CCAB:	Following Directions Tower Puzzle
75 min	F.A.T.S.:	Rifle Range Moving Targets
80 min	Grip Strength	
81 min	F.A.T.S.:	Quick Kill
85 min	CCAB:	Numbers and Words Route Planning
90 min	Temperature & Comfort Perceptions	
100 min	Metabolic rate: HR, BP, EMG	
103 min	F.A.T.S.:	Judgmental Shooting
108 min	CCAB:	Mark Numbers Missing Items
120 min	Temperature & Comfort Perceptions	
123 min	Metabolic rate: HR, BP, EMG	
126 min	Dexterity tests:	O'Connor Tweezer test Grooved Pegboard test
137 min	Shiver Suppression Techniques	
151 min	Temperature & Comfort Perceptions	
152 min	Metabolic rate: HR, BP, EMG	
155 min	End of Experiment	

Performance Parameters:

Grip Strength:

A hand dynamometer (Smedley Hand Dynamometer, Lafayette Instruments, Inc., Lafayette IN) was used to measure grip strength. Subjects, in a standing position, with dominant arm extended at their side and adducted, were instructed to squeeze the device as hard as possible without moving their arm. This was done prior to entering the chamber, at the 80 minute mark and just prior to the conclusion of the experiment.

Temperature & Comfort Perception Estimates (T/CP):

Subjects were required to place a mark on a 100 mm analog scale at the position that best represented their current level of comfort, and on a separate scale, their perception of how cold they were at that time. The scales used ranged from "cold" at 0 mm to "warm" at 100 mm for temperature perception, and "uncomfortable" at 0 to "comfortable" at 100 mm for comfort perception (Figure 1). The distance from 0 mm to the mark was measured directly with a mm scale and used for analysis. Such visual analog scales have been used extensively in pain studies (27) as well as cold perception studies (28). Temperature and comfort perception estimates were sampled every 30 minutes throughout each experiment beginning 30 minutes from the start of the experiment.

Subject ____________

Condition ______ Date ______

Test # ______

COLD ________________________________ WARM

UNCOMFORTABLE ________________________________ COMFORTABLE

Figure 1. Analog Temperature and Comfort Perception scale.

Complex, Cognitive, Assessment Battery (CCAB):

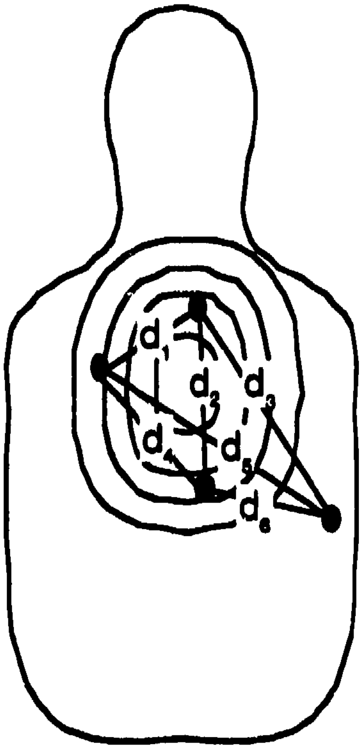
This battery of tests was developed for the U. S. Army Research Institute (29) to measure the spectrum of cognitive skills required in the performance of critical military command and control, operational tasks. The CCAB is a computer based test consisting of six subtests which provide measurements of attention to detail, perception of form, memory retrieval, time sharing, comprehension, concept formation, verbal reasoning, quantitative analysis, planning, situation assessment, decision making, problem solving and creativity. The CCAB instructions and cognitive tasks were displayed on a CRT screen located outside the environmental chamber, which the subject viewed through a 24" x 48" window. The subjects responded to CCAB test questions by typing answers on a keyboard mounted in front of the window inside the chamber. This keyboard was connected to an externally mounted IBM PS/2, Model 30/286 microcomputer (IBM Inc., Mc Lean, VA).

Firearms Training System (F.A.T.S.):

The Firearms Training System (Firearms Training System, Inc. Norcross, GA) combines interactive videodisc, computer and laser technology to provide for immediate visual performance feedback while firing at targets displayed by its projector. The subject is presented with a series of life-size scenarios projected onto a screen at the opposite end of the environmental chamber. When the F.A.T.S. weapon is fired, a laser is triggered and reflected momentarily on the screen. Its location on the screen is sensed by the video camera and recorded by the microcomputer. The F.A.T.S. calculates and prints, where applicable, reaction time, judgment, number of hits and or misses, and accuracy scores. The following is a brief description of the F.AT.S. simulations employed. All shooting was done from a standing position with the modified AR15-2 rifle provided as a component of the F.A.T.S.

Rifle Range Course:

Each subject was allotted one minute to fire ten shots at a stationary standard National Rifle Association (NRA) target at a simulated distance of 100 yards. Reloading was required after five shots. This sequence was repeated four times for a total of forty shots at four separate targets (10 shots/target x 4 targets). Shooting accuracy was analyzed by calculating the mean distance between shots (Figure 2). This assumes that the center of the shot grouping was the zero point, and was used to avoid any problems associated with F.A.T.S. system misalignment.



$$\underline{\text{Mean shot distance}} = \frac{\sum_{n}^{1} d}{n}$$

```
where d = distance in inches
      n = number of measurements
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Figure 2. This is a sample fixed range target. The dots represent the hitpoints and the distances (d_1 - d_n) are the values used to calculate the mean distance between shots.

Moving Targets:

Each subject fired a maximum of eight rounds at eight pop-up and/or moving targets. Targets consisted of a video sequence of an actual moving target range with a mix of stationary and moving pop-up targets that presented 8 targets in sequence to the marksman. The actual number of shots fired (8 possible) and the number of targets hit were recorded.

Quick Kill:

The subject had 30 seconds to fire 54 shots at 54 targets of differing sizes and shapes which flashed rapidly on the screen in random locations. The number of shots fired and targets hit were recorded.

Judgmental Shooting:

The subject was presented with 5 realistic audio-visual scenarios depicting situations which might require the use of the weapon (2 no-shoot and 3 shoot situations presented in random order). The scenarios used in Phase I of the experiments were selected from the 40 existing standard simulations accompanying the F.A.T.S. system, currently configured for law enforcement officers. The scenarios were drawn from the FBI Police Officer Killed statistics and filmed at the

Federal Law Enforcement Training Center at Glynco, Georgia. All of these scenarios were scripted from actual incidents in which deadly force was required or where it was used in error. Some of the scenarios had a similar beginning but ended differently in either a "Shoot" or "No-Shoot" situation. Scenarios were selected so that a subject was exposed to different scenarios in each condition. The subject was required to anticipate the different threat levels associated with the various weapons depicted in the scenarios - knives, handguns, rifles, shotguns, etc. and respond appropriately. The subject was instructed to fire the weapon at least twice if he judged the scenario to be a shoot situation. The scenario continued until two hits were registered or the threat was over. Decision making, reaction time, and accuracy were evaluated.

Dexterity Evaluations:

Manual dexterity was evaluated using a modified O'Connor Tweezer Dexterity Test and the Grooved Pegboard Test (Lafayette Instruments, Lafayette, IN). In the standard O'Connor Tweezer Dexterity Test the time needed to fill a board containing a 10 x 10 matrix of holes with metal pins, using a tweezer to manipulate the pins, is recorded. This procedure was modified based on preliminary data which indicated that under cold exposure conditions completion time was excessive for the design of this protocol. In the modified version subjects were allowed 3 minutes to insert as many pins as possible, and any dropped pins were recorded. The Grooved Pegboard Test required subjects to use their fingers to insert in sequence, 25 key-shaped pegs into corresponding holes in a plastic board. Subjects were timed and dropped pegs were recorded. Subjects used their dominant hand for both dexterity tests.

Physiological Parameters:

Temperatures:

Temperatures were monitored and recorded every minute using a Macintosh SE microcomputer (Apple, Inc.), interfaced with an A/D board and data handling software (Analog Connection Workbench, Strawberry Tree, Inc., Sunnyvale, CA). In addition, digital temperature monitors (TH-8, Sensortek, Inc.) were used to monitor the surface and rectal temperatures and to provide backup data logged by hand at 5 minute intervals. Core temperature was monitored with a disposable rectal temperature probe (Type T, Sensortek, Inc.) inserted approximately 8 cm past the anus. Skin temperatures were monitored on the calf, thigh, upper arm and chest using skin surface thermocouples (Model #SST-1,Type T, Sensortek, Inc.) (see Figure 3a for placement). Mean skin temperature (T_{MS})was calculated using Equation 1(30):

$$(T_{MS}) = 0.3(\text{chest} + \text{arm}) + 0.2(\text{calf} + \text{thigh}) \qquad (1)$$

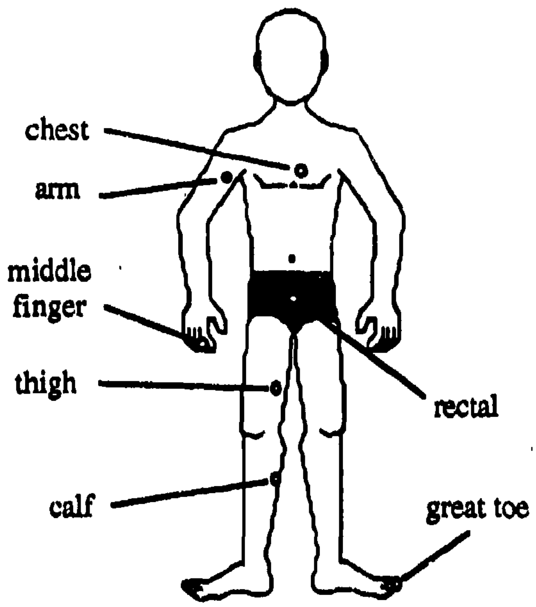

Figure 3a. Thermocouple placement

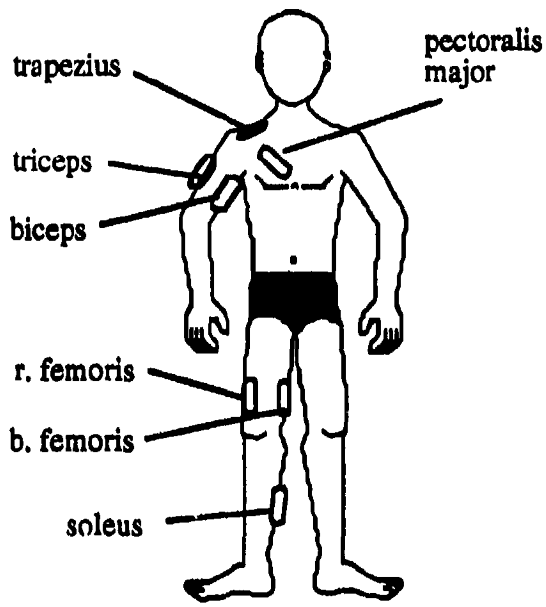

Figure 3b. EMG electrode placement

Electromyograms (EMG)/Acceleration:

Surface electromyogram electrodes (Model #D550, AA Biomedical, Inc., Windsor, CA) were placed on the trapezius, pectoralis major, biceps brachii, triceps brachii, rectus femorus, biceps femorus and soleus muscles (see Figure 3b for placement). Electromyograms and acceleration signals were amplified and monitored on a Nicolet Viking (Nicolet Biomedical Instruments, Madison, WI) while being recorded on magnetic tape for subsequent analysis. The EMG signal was sampled at pre-determined times (12, 24, 36, 48, 60, 100, 125, and 145 min.) during the cold exposure.

Vertical and horizontal acceleration of the rifle barrel before, during, and after shooting were monitored by an accelerometer (GY 125-10, Kulite Semiconductor Products, Inc., Ridgefield, NJ) mounted at a 45° angle on the rifle barrel, 5 cm from the end of the muzzle (Figure 4). Acceleration (as a measure of steadiness) of the rifle barrel was monitored and recorded on magnetic tape while taking aim during the rifle range simulations.

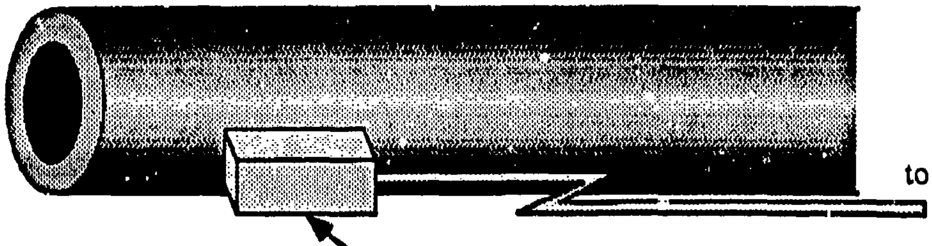

Figure 4. Accelerometer placement on barrel of AR15-2.

Analysis of EMG and acceleration signals consisted of digitizing recorded data with a DEC VAXLab GPX (Digital Equipment, Co. Marlboro, MA) computer using software developed on site, utilizing ILS (Signal Technology, Inc., Goleta, CA) data acquisition routines. This software was also used to compute the root mean square voltage (RMS) of pertinent 30 second samples of each EMG according to the following algorithm.

$$\mathrm{RMS} = \sqrt{\frac{y_1^2 + y_2^2 \cdots y_n^2}{n}}$$

where y = voltage of EMG and n = number of points sampled

Acceleration signals were analyzed with samples obtained from periods immediately before a shot. The periods before the first, fourth and 31st shots (rifle range course) were selected to provide data from a cross section of possibilities, e.g. first shot: at the beginning of the sequence, fourth shot : middle of a clip, and the 31st shot: near the end of the firing sequence. Statistical analysis (ANOVA, t-tests) was then performed using the RMS data.

Respiratory & Metabolic Measurements:

Minute ventilation and expired carbon dioxide production were monitored using a Rayfield open circuit spirometry sampling system (Rayfield, Ltd., Waitsfield, VT) and analyzed using the methodology developed by Rayfield (31). ECG was monitored by telemetry (Transkinetics Inc., Canton, MA). Blood pressures were measured by sphygmo-manometer and stethoscope. These variables were recorded at 12 minute intervals during the first hour and at 20 minute intervals over the remainder of the experiment. Two ECG electrodes were placed on the chest for cardiac monitoring.

Shiver Suppression:

Four shiver suppression methods, selected from preliminary experiments, were employed:

(1) Breath hold: The subject was instructed to hold his breath for 30 seconds.

(2) Relax: The subject was instructed to stand still and attempt to relax his entire body for one minute.

(3) Warm Water: The subject was instructed to drink a six ounce cup of warm (50° C) water within one minute.

(4) Mental Arithmetic: Two columns of random two digit numbers were displayed side by side on a sheet of paper. The subject was instructed to add as many of these pairs together as he could in one minute, verbalizing each answer.

Cards with instructions for each shiver suppression method were placed face down in front of the subject. After standing for two minutes while uninhibited levels of shivering were recorded, the subject read the first shiver suppression card and followed the instructions when signaled to proceed. This same procedure was repeated until all four shiver inhibition techniques were completed.

In order to evaluate the shiver suppression techniques, a control RMS value was calculated as follows: EMGs of shivering muscles were recorded and RMS values for all muscle groups were obtained while the subjects were shivering in a standing position, over a 30 second period during the two minutes prior to the application of a suppression maneuver. This value was used as the control RMS value. The RMS value was then re-computed after the onset of the suppression maneuver, and this value was used as the post-test measure (timing details are covered earlier on p. 8 and in Appendix I, p. I - 5).

Results

Rectal and Mean Skin Temperatures:

There were no significant differences between conditions in rectal temperature change (beginning and ending temperatures), with all conditions exhibiting approximately 0.2°C drop . If maximum and minimum temps are compared, there were still no significant differences except where exercise is involved (c/w/e & c/w/e/f) (see Table 3).

Table 3. Rectal temperature changes

	c	c/w	c/w/f	c/w/e	c/w/e/f	warm
0-end	0.24	0.21	0.29	0.20	0.19	0.24
0-min	0.30	0.24	0.32	0.20	0.19	0.36
max-end	0.33	0.32	0.41	0.86	0.97	0.25
max-min	0.39	0.35	0.44	0.86	0.97	0.37

During the two exercise conditions (4 & 5) rectal (core) temperatures rose significantly (approximately 0.6°C) while exercising but fell to the same level as the other conditions by the end of exposure time (Figure 5).

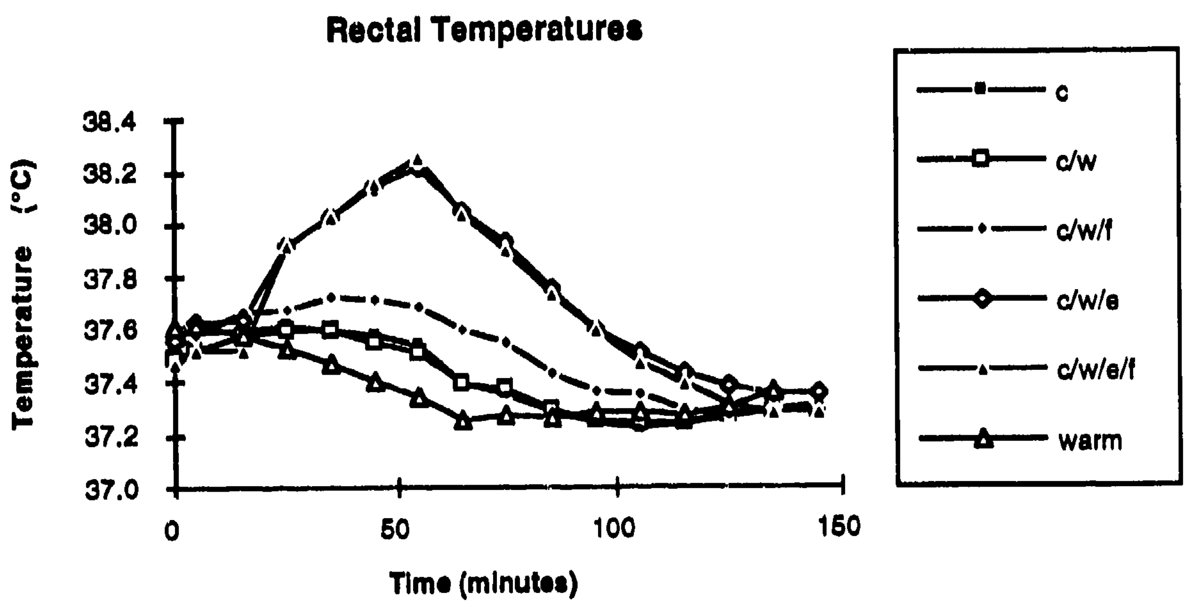

Figure 5. Each point represents the mean rectal temperatures of all subjects for each condition.

Conditions 1, 2, and 3 (cold exposures, no exercise) exhibited nearly identical rectal temperature curves over the time of the exposure (cold stress). The warm condition showed a similar trend, but did not rise above the level seen at the start of the experiment while conditions 1 - 3 showed slight increases in rectal temperature until approximately minute 35 at which time temperatures dropped steadily. The time/temperature curve in conditions 4 and 5 (with 2 twelve minute exercise sessions in the first 60 minutes) deviated from that seen in the conditions without exercise as would be expected. Rectal temperature began to increase in conditions 4 and 5 following the onset of exercise at minute twelve. Although exercise was discontinued at minute 48 of the protocol, the core (rectal) temperature continued to rise until minute 55. Subsequently core temperature decreased to the level attained in the non-exercise conditions. The shapes of the temperature curves for conditions 4 and 5 did not differ significantly.

Rectal temperatures in the warm condition dropped to a point lower than that seen in all other conditions, probably due to the fact that there was no shivering, vasoconstriction, or exercise taking place to either generate or conserve heat. Subjects were primarily sitting quietly for the first hour of the experiment. During the second hour subjects were more active, performing the various shooting, dexterity, and cognitive tasks. Under these more active conditions, rectal temperatures remained nearly constant as in the cold and cold wet conditions.

Mean skin temperatures fell slightly more than 5°C during the cold exposures (see Table 4). This is contrasted with a drop of only 1.4°C in the warm condition.The greatest drop in mean skin temperatures occurred within the first 75 to 85 minutes of exposure in conditions 1-5, with relatively little additional cooling demonstrated during the last 50-60 minutes of exposure. There were no significant differences between cold conditions in the rates of fall of mean skin temperatures or the shape of the cooling curves (see Figure 6). Mean skin temperatures in the warm condition showed a slight but steady decline over the course of time.

Rectal and mean skin surface temperatures for individual subjects in each condition are presented in Appendix II, Tables 1-12.

Table 4. Mean skin temperature changes

	c	c/w	c/w/f	c/w/e	c/w/e/f	warm
0-end	4.98	5.25	5.14	5.06	5.87	1.42
0-low	5.24	5.58	5.14	5.14	5.87	1.38

note: 0 minutes = maximum mean skin temperature in all cases.

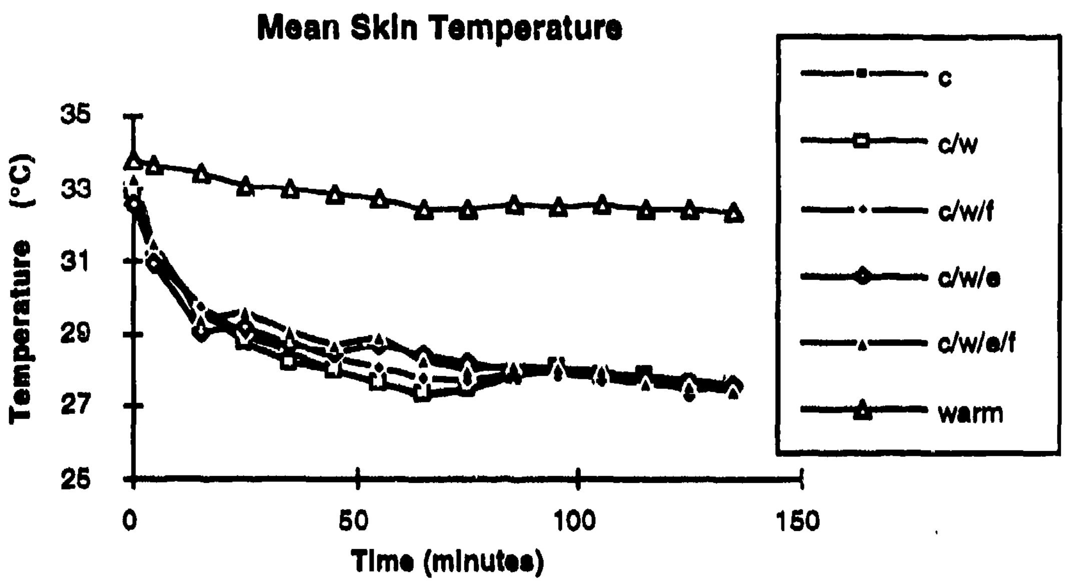

Figure 6. Temperatures represent the mean of mean skin temperatures of all subjects for each condition.

Temperature and Comfort Perception:

Temperature and comfort perceptions correlated very well in all conditions showing little difference between perceptions of comfort and temperature. Both temperature and comfort perceptions correlated well with mean skin temperatures (Figure 7), but not with the less

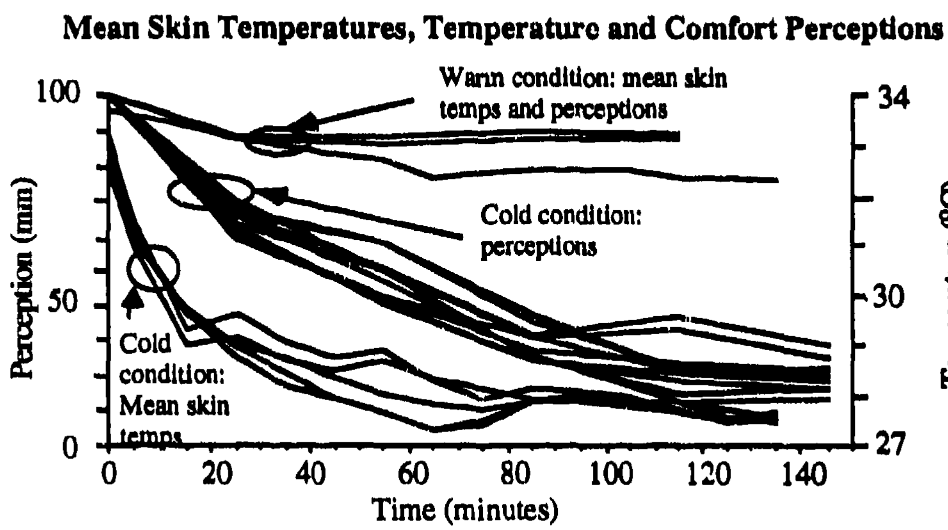

Figure 7. Temperature and comfort perceptions plotted with mean skin temperatures to illustrate correlations.

dramatic changes seen in core (rectal) temperatures. Although measured rectal temperatures increased significantly following exercise in conditions 4 and 5, this was not reflected by increases in temperature perception or comfort perception ratings

The ratings of temperature and comfort perception for all subjects across all conditions are presented in Appendix III, Tables 1-6.

Rifle Shooting Performance - Firearms Training System (F.A.T.S.)

a. Rifle Range Course:

When the sizes of the shot groupings were analyzed by computing the average distance between shots, the smallest average amount of scatter (the tightest shot grouping) was in the warm condition (condition 6), followed in order by conditions 5, 4, 2, 3 (c/w/e/f, c/w/e, c/w and c/w/f) and finally condition 1 (cold) as the least accurate (Figure 8).

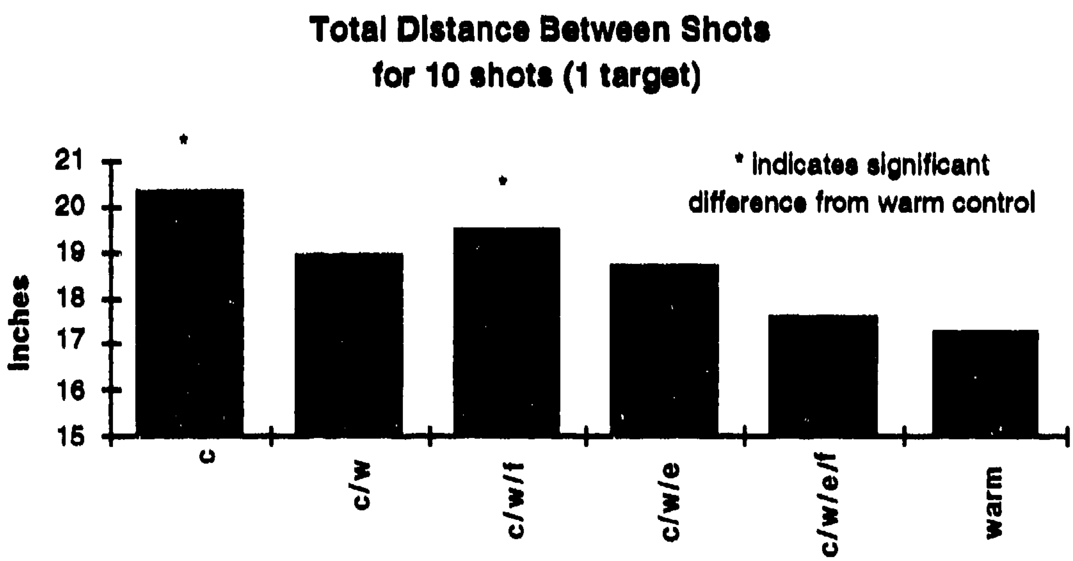

Figure 8. Total distance between 10 shots (spread per target).

Greater decrements due to the cold may have been seen later in the cold exposure. The range shooting took place relatively early in the experiment at the 75 minute mark. At this point in time rectal temperatures were generally at about the midpoint of their range for 4 of the conditions and core temperatures were still above the starting point in the 2 exercise conditions. (Figure 5) .

The shooting performances of all subjects on the simulated 100 yard rifle range course in each condition are presented in Table 1, Appendix IV.

b. Moving Target Range Course:

Although subjects generally demonstrated the poorest accuracy on moving targets during condition 5, there were no statistically significant differences between conditions for either number of target hits or the ratio of hits to number of shots fired (Figure 9).

The shooting performances of all subjects on the Moving Target Range Course in each condition are presented in Table 2, Appendix IV.

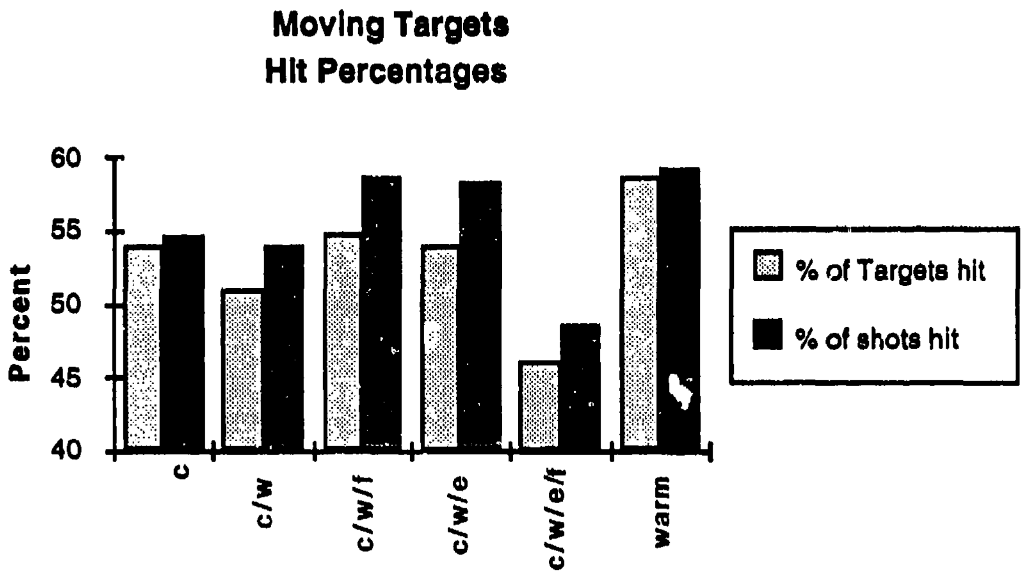

Figure 9.Percentage of shots fired that hit a target and percentage of targets hit (8 possible).

c. Quick Kill Course:

There were no statistically significant differences in shooting performance between cold conditions for either the number of hits, the percentage of targets hit, or the ratio of hits to shots fired, although slightly poorer average performance occurred in the cold condition (condition 1) across all three of these performance indices. Performance was significantly poorer than control (warm condition) for the percentage of shots that hit the target in all cold conditions except c/w (paired t-test, $p \leq 0.05$) (Figure 10). On the other hand, the percentage of targets hit showed no significant differences between conditions. These data, when taken together, indicate that subjects were firing more shots in the cold conditions, but not hitting any more or any fewer targets than in the warm condition.

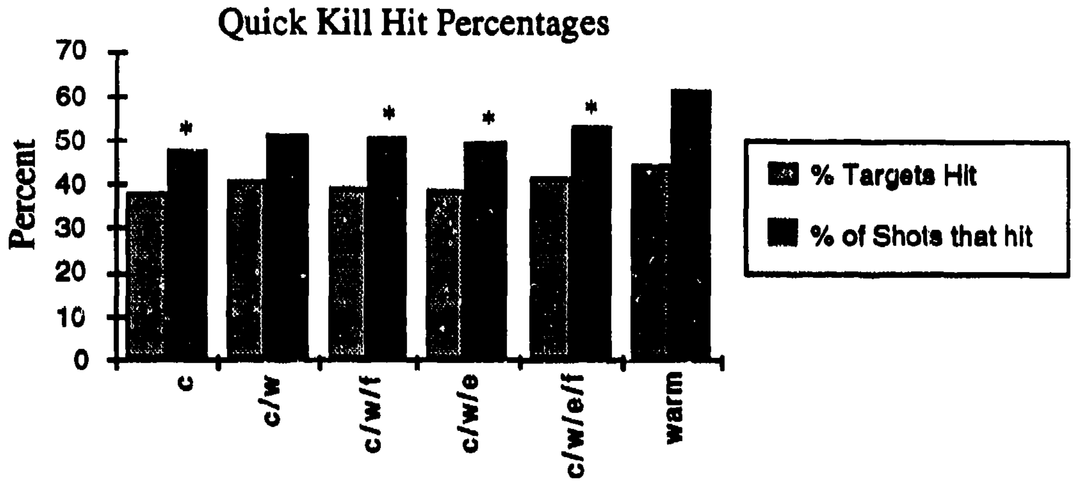

Figure 10. Quick Kill mean percentages of hits for targets (# targets hit/54 possible targets) and shots actually fired (# shots that hit/# shots fired). * indicates significant difference from warm.

The shooting performances of all subjects on the Quick Kill Range Course (rapid fire) in each condition are presented in Table 3 of Appendix IV.

d. Judgmental Shooting:

Several combinations of stressors resulted in significant impairment of judgment during the shoot/no-shoot scenarios (ANOVA, $p \leq 0.05$). The c/w, c/w/e, and c/w/e/f conditions (conditions 2, 4 and 5) all resulted in reduced percentages of correct judgments (Figure 11).

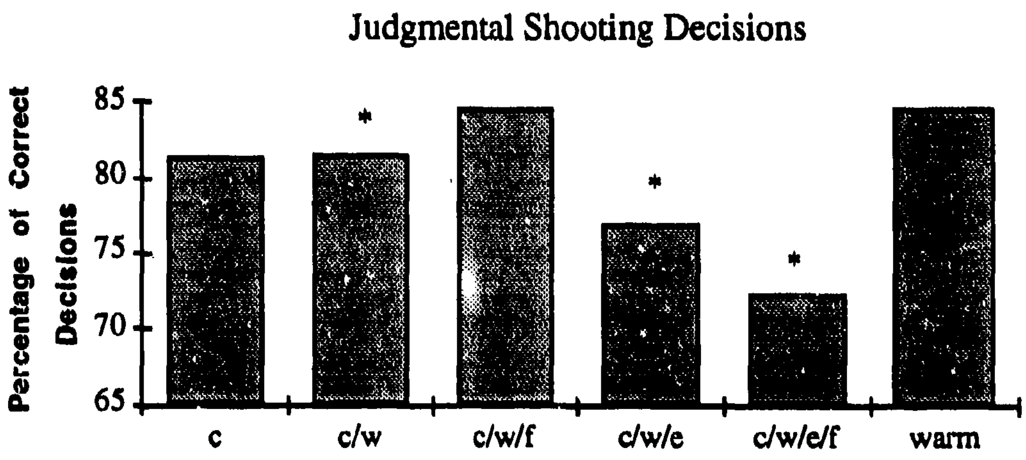

Figure 11.Percentage of correct shoot or no-shoot decisions during Judgmental shooting scenarios. An * indicates significant change from the Control (Warm) condition.

This does not seem to be due solely to changes in reaction time. Mean reaction times in c/w and c/w/e/f conditions (2 and 5) were slower than mean reaction times in the control condition 6; the mean reaction time in condition 4 (c/w/e) was faster than control (Figure 12). The only statistically significant difference in reaction times was between c/w/e and c/w/e/f.

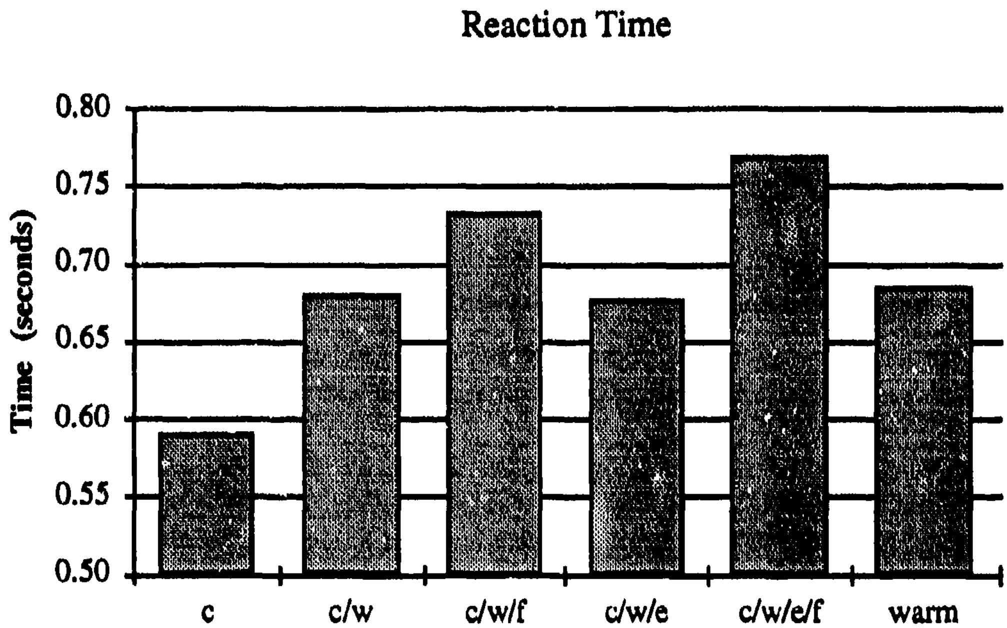

Figure 12. Time between onset of threat presented and the first shot. Conditions c/w/e and c/w/e/f were significantly different from each other ($p \leq 0.05$).

There was no significant effect of condition on shooting accuracy during these tests as measured by percentageof shots that hit the desired target.

The shooting performance of all subjects reacting to the shoot/no shoot video scenarios in the Judgmental Shooting course in each condition are presented in Table 4 of Appendix IV.

Grip Strength:

Post-test grip strength means were significantly lower (paired t-test, $p \leq 0.05$) than pre-test means for all cold conditions (Figure 13). There was, however, no statistically significant difference in grip strength decrement between the various cold conditions (one-way ANOVA). The warm control showed no significant decrement from beginning to end of the experiment.

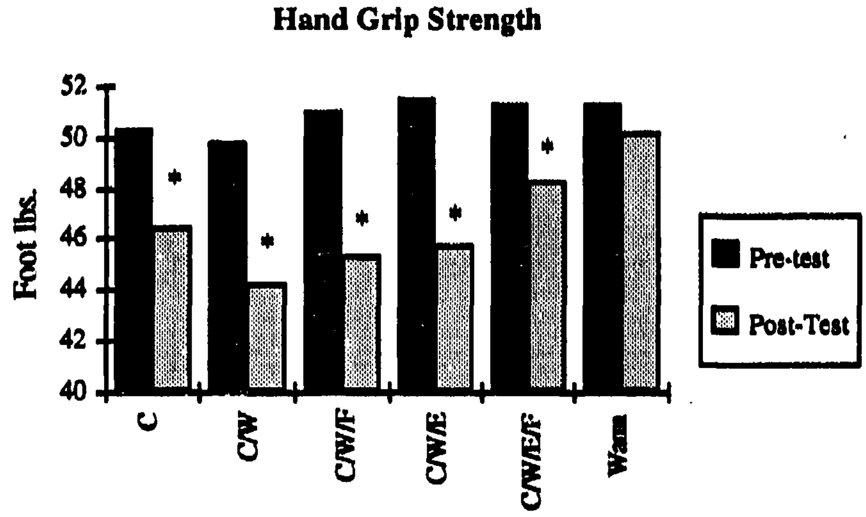

Figure 13. Grip strength. Columns with * are significantly lower than their corresponding pre-test values.

Percentage drops in grip strength ranged from 5.3% in condition five to 11.5% in condition four, with average decrements of 7.3%, 10.3% and 11.1% in conditions one, two and three respectively. The slight decrease seen in condition 6 (warm) was not a significant drop.

Individual pre and post grip strength measurements within each condition are reported in Appendix V, Table 1.

Dexterity Tests:

There were significant differences (paired t-tests, $p \leq 0.05$) between the warm control and all cold stress conditions for the number of pins correctly placed on the O'Connor board, demonstrating impairment due to the cold exposure in all cold conditions (conditions 1-5). (Figure 14).

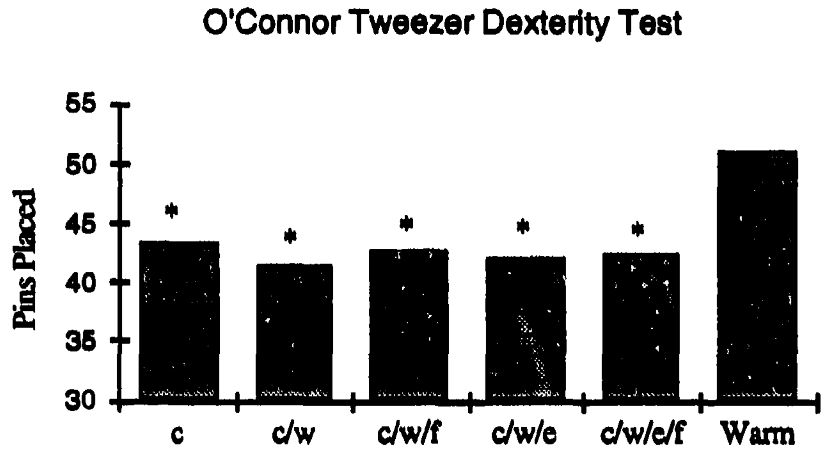

Figure 14. Number of pins placed within 1 minute during the O'Connor Tweezer Dexterity Test (* indicates significant changes from control (p ≤ 0.05)

There was also a significant effect due to cold exposure across all conditions in the time needed to complete the Grooved Pegboard task (ANOVA, p ≤.05), with the slowest average time evidenced in the c/w/e condition, followed by c/w/e/f, c/w/f, c/w and c (conditions 5, 3, 2 and 1) respectively (Figure 15). There were no significant differences between the five cold conditions, however the trend indicates that the addition of multiple stressors may cause a decrease in performance.

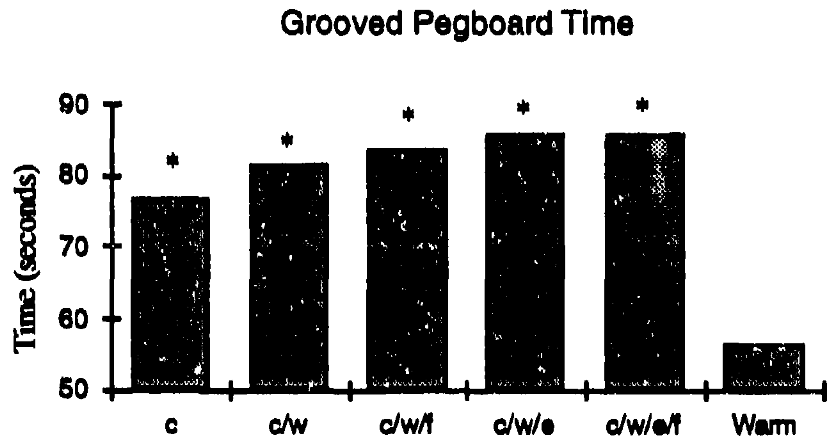

Figure 15. Time in seconds needed to fill the 25 holes in the Grooved Pegboard. (* indicates significant changes from control (p ≤ 0.05)

There were no significant differences in number of pins or pegs dropped, nor were there significant differences between cold conditions (one-way ANOVA) in number of pins placed on the O'Connor or time needed for the Grooved Pegboard tests.

The performance of individuals on each of the measures of the O'Connor Tweezer Dexterity Test and the Grooved Pegboard are presented in Table 2 in Appendix V.

Complex Cognitive Assessment Battery:

Across all cold stress conditions, the highest scores were generally achieved in condition 5 (cold/wet/exercise/fatigue). This condition exhibited the highest or second highest average score of any condition for five of the six CCAB sub-tests (Following Directions, Tower Puzzle, Numbers and Words, Mark Numbers and Route Planning). There were no significant differences between CCAB sub-tests taken separately within each condition, and there was no significant overall effect on CCAB sub-test scores between conditions.

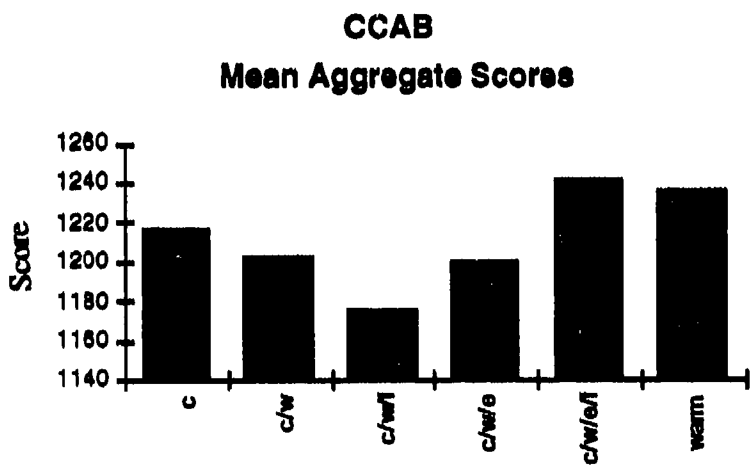

Figure 16. CCAB scores. Mean, aggregate (total of the 6 sub-tests) scores of all subjects.

Although subjects were sleep deprived in conditions 3 and 5, sleep deprivation of 24 hours duration did not contribute to significant declines in cognitive performance on individual sub-tests of the CCAB, nor did exercise contribute to significant changes in either direction. The total aggregate scores of all sub-tests of the CCAB combined, however, were highest in the c/w/e/f, warm and cold conditions (conditions 5, 6 and 1 in that order), with the aggregate overall scores in the c/w, c/w/f and c/w/e conditions (conditions 2, 3 and 4) significantly lower (paired t-tests, $p \leq 0.05$) than the warm condition (control) or condition 5 (cold/wet/exercise/fatigue).

The performances of all subjects on each of the sub-tests of the Complex Cognitive Assessment Battery (CCAB) are presented for each condition in Tables 1-6 in Appendix VI.

Cardiovascular and Respiratory Responses:

The electrocardiogram was monitored throughout the experiment as part of the human subject safety protocol. No abnormal rhythms were observed during any of the experiments. The systolic and diastolic blood pressures were monitored during the first hour of the experiment to coincide with the exercise portion of conditions 4 and 5 (c/w/e, c/w/e/f). No systolic or diastolic blood pressures (under conditions of rest or exercise) were observed that would have exceeded the acceptable limits set for the stress testing protocol (Materials & Methods, Volunteer selection and screening, p. 5) used initially in screening the subjects for participation in the program.

Cardiovascular:

During the first hour of cold exposure, there were minimal changes in heart rate and blood pressure except during the exercise portion of conditions 4 and 5.

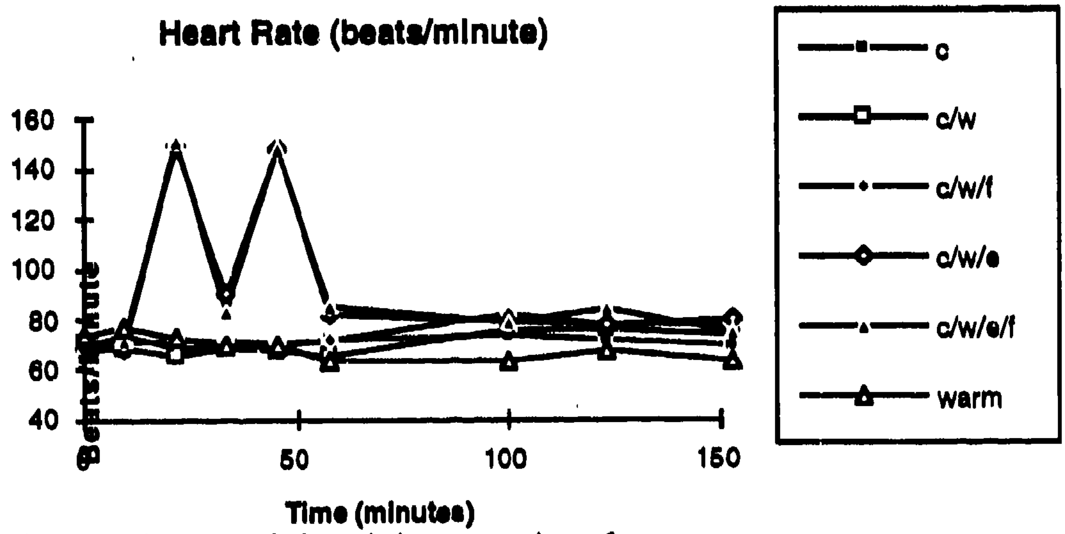

Figure 17. Heart rate in beats/minute over time of exposure.

In the c/w/e and c/w/e/f conditions the systolic blood pressure increased by approximately 40% during exercise and the diastolic pressure decreased slightly or remained constant (Figures 18 and 19).

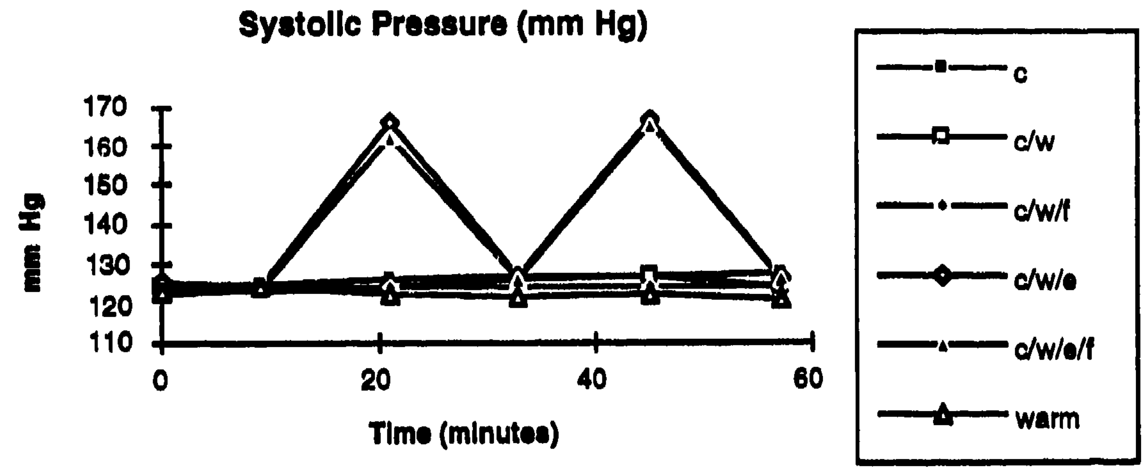

Figure 18. Systolic blood pressure over time of exposure in mmHg.

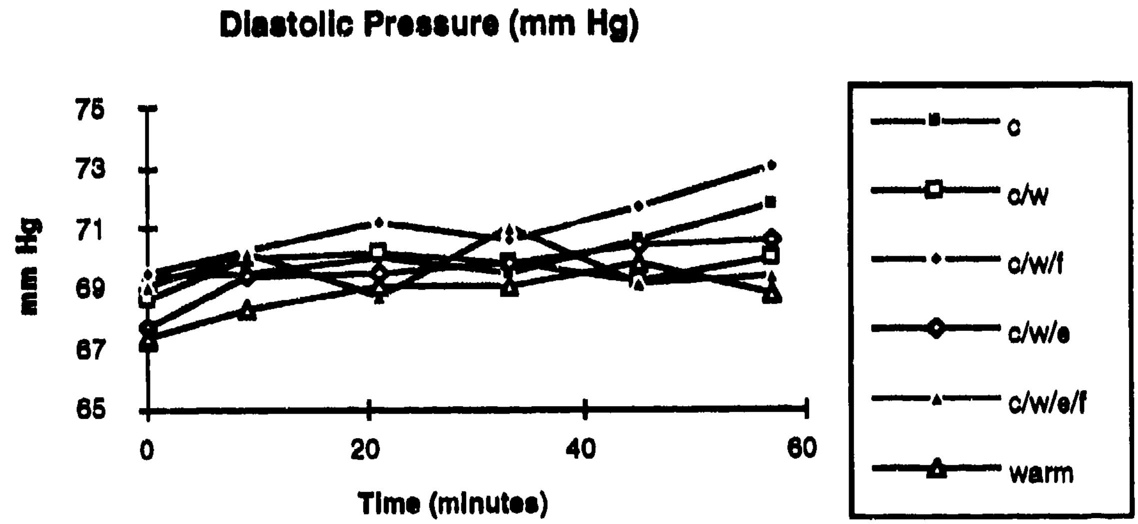

Figure 19. Diastolic blood pressure over time of exposure in mmHg.

Between the first and second exercise period the heart rate remained elevated, but the systolic and diastolic blood pressures returned to pre-exercising levels.

Respiratory:

The respiratory data is summarized in Figures 20-22. Respiratory changes for the non-exercising portions of all conditions showed a similar pattern. Minute ventilation ($\dot{V}E$) increased in the cold conditions, rising slowly during the first 2 hours of the test period.

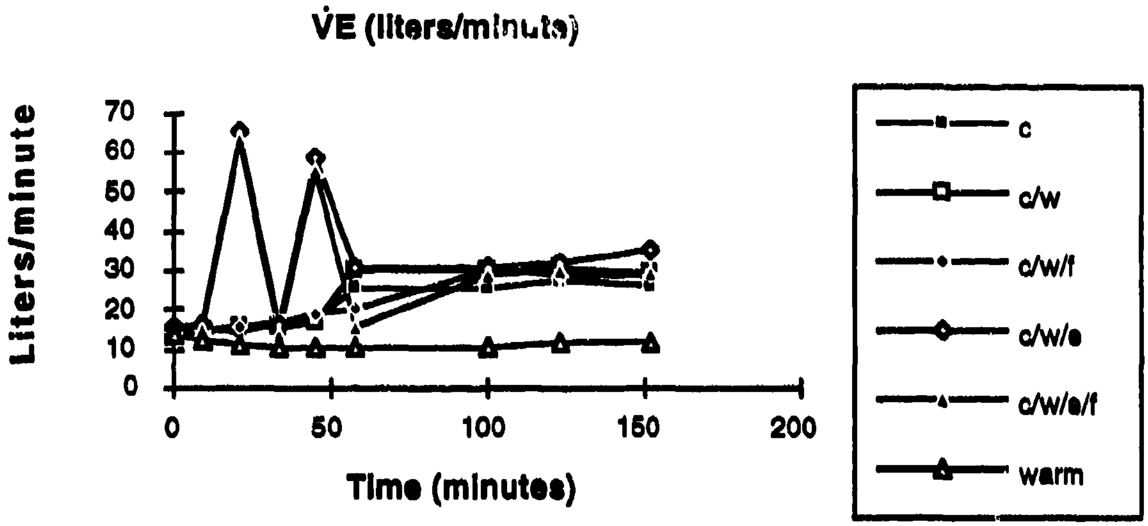

Figure 20. Minute ventilation over the course of exposure in liters/minute.

The observed increase in minute ventilation is due to an increase in tidal volume since the respiratory rate showed little or no change from the control level obtained prior to entering the environmental chamber.

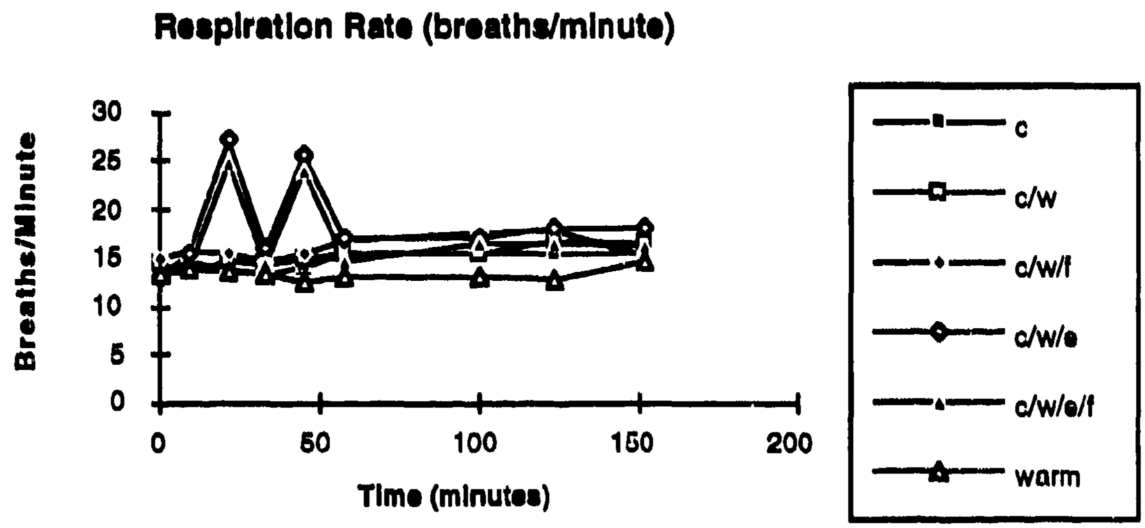

Figure 21. Respiration rate in breaths/minute over the course of exposure.

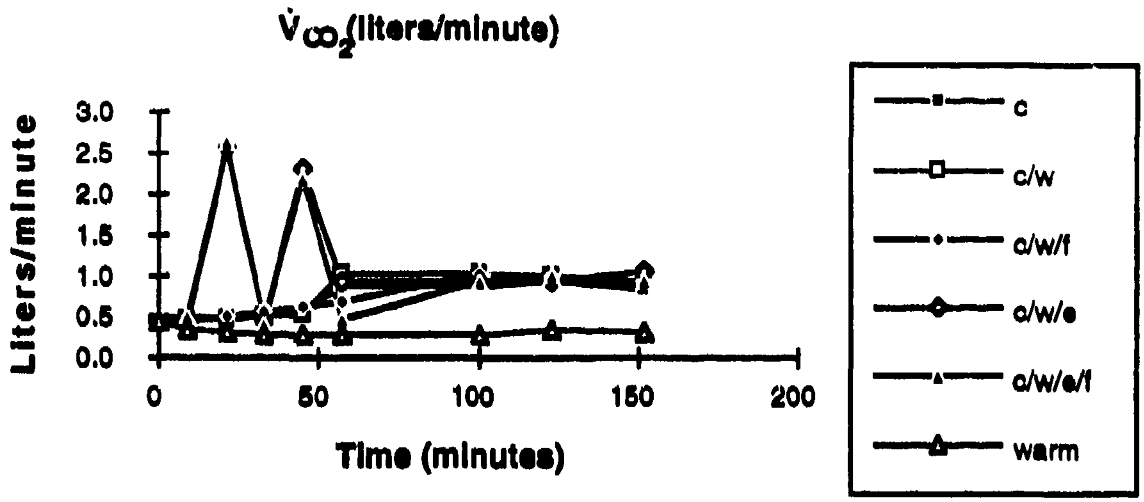

Figure 22. Carbon dioxide production in liters/minute.

During the exercise portion of conditions 4 and 5 there was a large increase in all respiratory parameters (see Figures 20 -22). At the point midway between the two exercise periods the respiratory parameters returned to normal levels.

The cardiovascular and respiratory data, for individual subjects in each of the six conditions are presented in Tables 1-6, Appendix VII.

Shivering

The EMG RMS values from the warm condition were considered to be control values, and all other RMS determinations were expressed as changes from their control values. For an overall characterization of the subjects' shivering during the exposure period, the average RMS values for all seven muscles, at each sample time, and for each condition, are summarized in Figure 23. The progression of shivering activity varied depending on the condition. Shivering increased progressively throughout the first hour of exposure during the c, c/w, and c/w/f conditions. In the second hour, shivering peaked and began to decrease in condition 1 (cold) but continued to increase in the c/w and c/w/f conditions. In both conditions incorporating an exercise component (c/w/e, c/w/e/f), the increase in shivering activity as indicated by changes in RMS voltage was significantly delayed until after the two exercise bouts. Nonetheless, by 100 minutes shivering had reached levels similar to those observed in conditions 1 and 3. The c/w condition, however, consistently resulted in the highest levels of shivering activity.

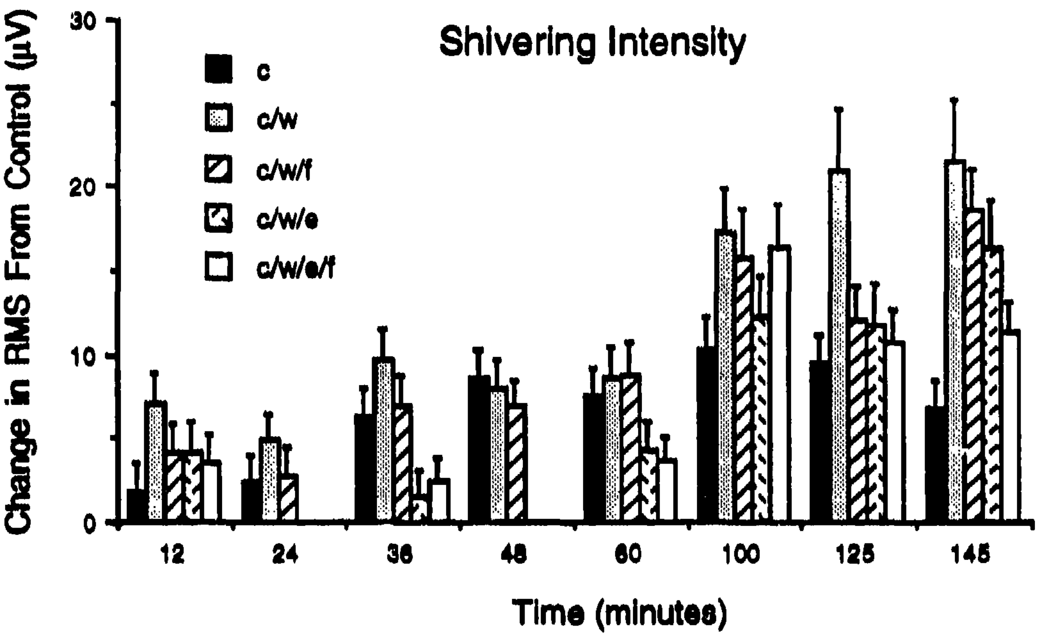

Figure 23. For each subject the difference between mean RMS voltage for each condition and control was computed. The mean ± 1 SEM of all seven muscles is presented here. EMG data was not collected during exercise bouts due to interference from voluntary motion.

The response and activity of the individual muscle groups during the cold exposure varied considerably. Data for each muscle monitored, in each of the five conditions, is presented in Figures 24-28. Regardless of the condition, the trapezius showed the greatest overall activity. In condition 1 (c), the activity in the trapezius was not only greater than that of other muscles, but increased to a greater extent through the first 125 minutes of exposure. The six other muscles monitored showed gradual increases in activity during the early part of cold exposures with essentially no difference in shivering intensity between muscles (Figure 24). In the c/w and c/w/f conditions shivering intensity showed similar patterns, with the largest RMS values again seen in the trapezius (see Figures 25 and 26). The pattern of shivering from 100 minutes to the end of the test was similar in all conditions.

In conditions 4 and 5 (c/w/e & c/w/e/f), two 12 minute exercise periods were included in the first hour of cold exposure (at 12 and 36 minutes). In both of these conditions shivering, as indicated by the RMS values, was slightly reduced by the exercise bouts up to 100 minutes into the exposures; EMG data was not collected during the exercise bouts at 24 and 48 minutes due to the interference that would obscure the shivering activity during exercise (Figures 27 & 28).

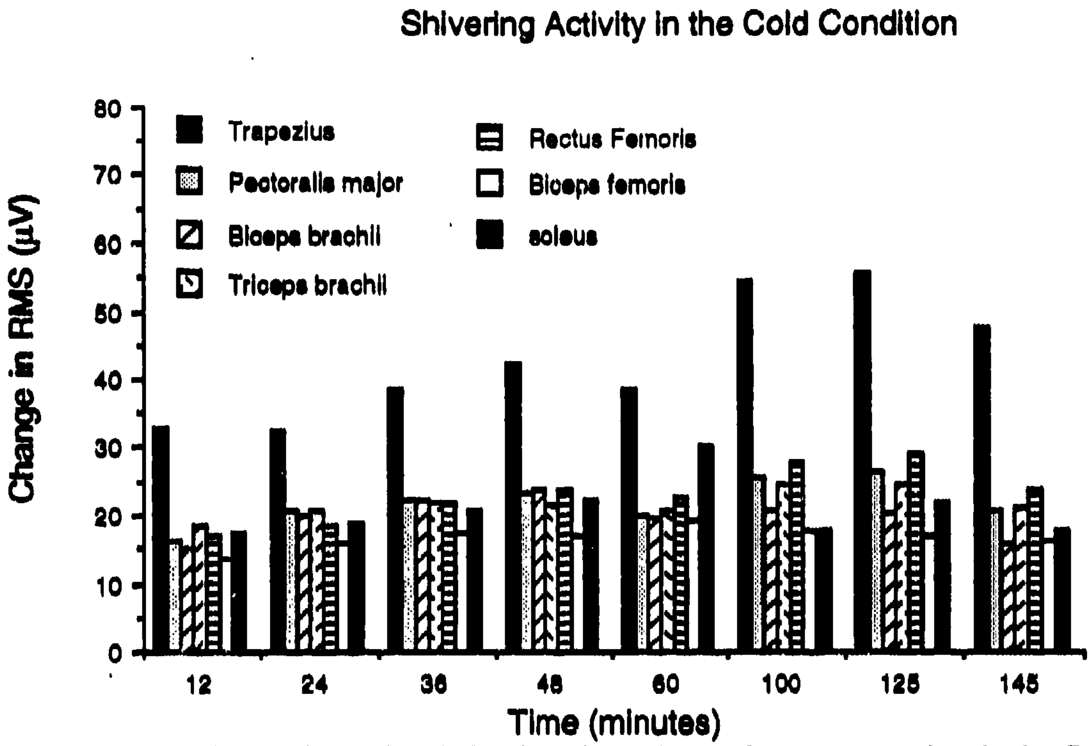

Figure 24. The change in RMS values for each muscle group over time in the Cold (Condition 1) protocol.

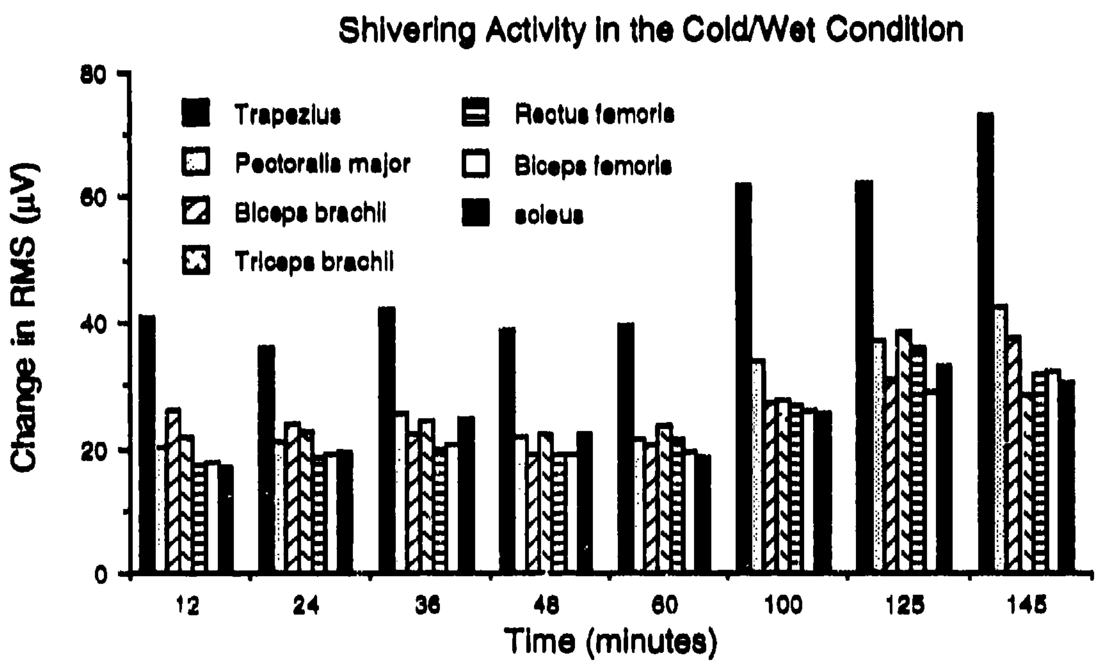

Figure 25. The change in RMS values for each muscle group over time in the Cold/Wet (Condition 2) protocol.

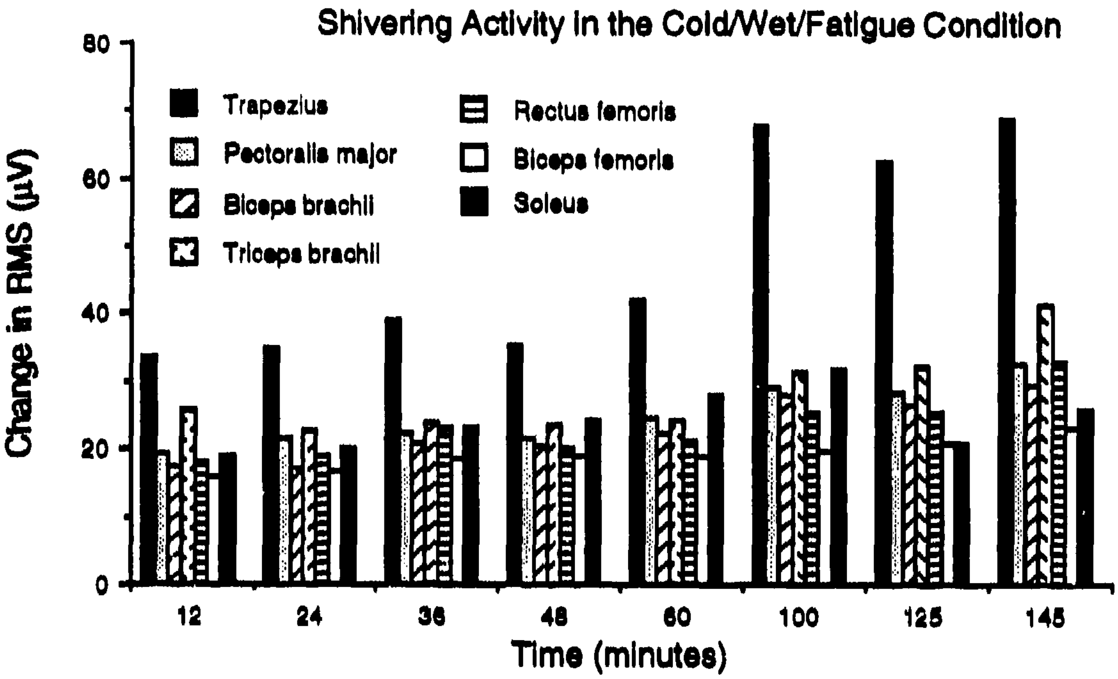

Figure 26.The change in RMS values for each muscle group over time in the Cold/Wet/Fatigue (Condition 3 protocol).

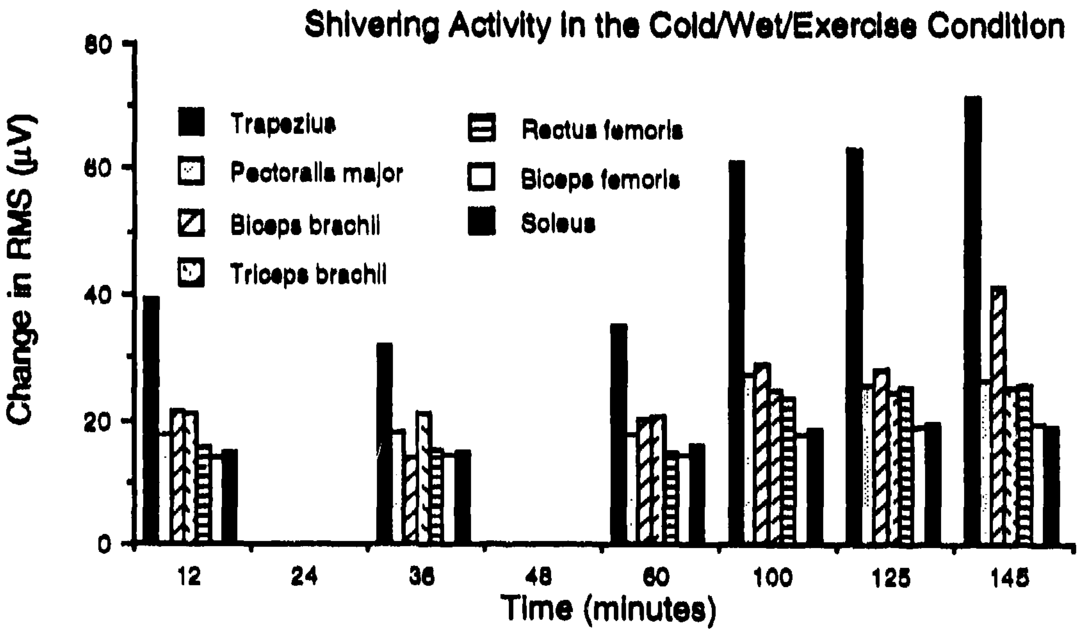

Figure 27. The change in RMS values for each muscle group over time in the Cold/Wet/Exercise (Condition 4) protocol. EMG data was not collected during exercise bouts due to interference from voluntary motion.

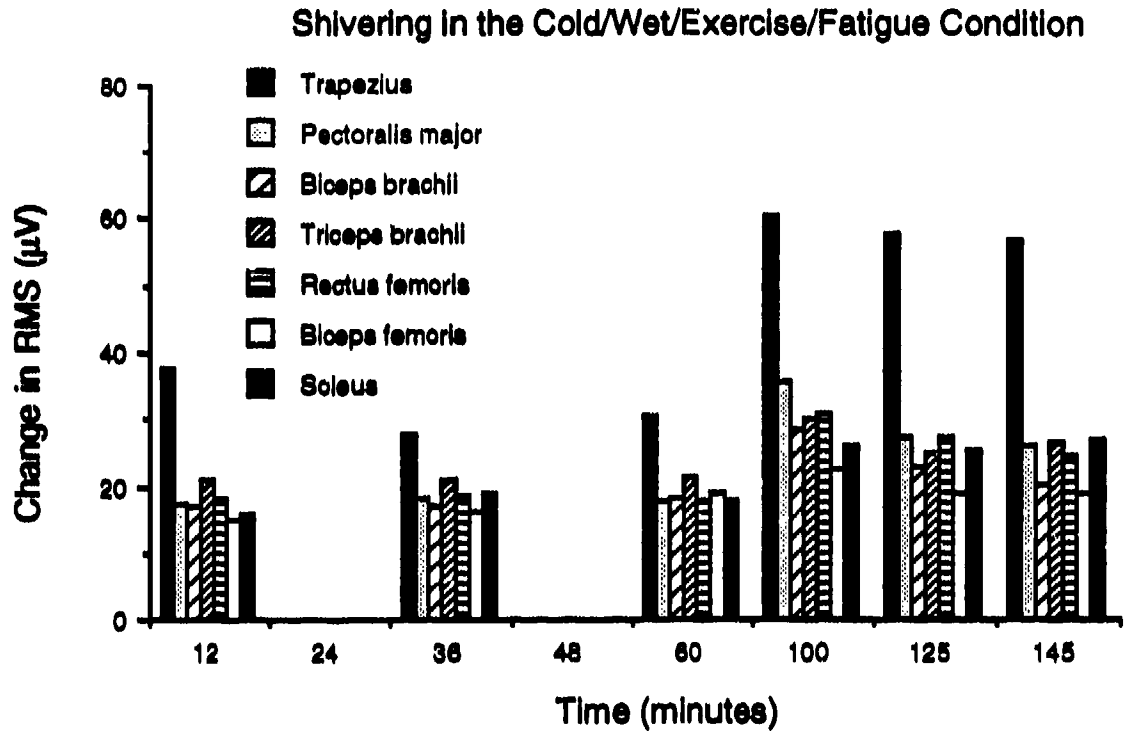

Figure 28. The change in RMS values for each muscle group over time in the Cold/Wet/ Exercise/Fatigue (Condition 5) protocol. EMG data was not collected during exercise bouts due to interference from voluntary motion.

Shivering was expected to result in increased movement of the rifle during the rifle range target shooting portion of the experiment. In order to monitor the movement an accelerometer was attached to the rifle barrel and the voltage output representing acceleration was recorded. The acceleration data was analyzed in the same manner as the EMG output, *i.e.* RMS voltage with the appropriate calibration factor to express the end result in units of acceleration. Figure 29 presents the acceleration data for the five cold conditions. In each condition the acceleration signal was analyzed following the 1st, 4th and 31st shots (each subject was allowed 10 shots at each of 4 targets for a total of 40 shots) (Materials & Methods, Rifle Range Course, p. 10). There was no statistically significant difference between shots or between conditions, however the c/w condition consistently tended to cause the most rifle movement, followed by conditions 1,3,4, and 5 (c, c/w/f, c/w/e, & c/w/e/f).

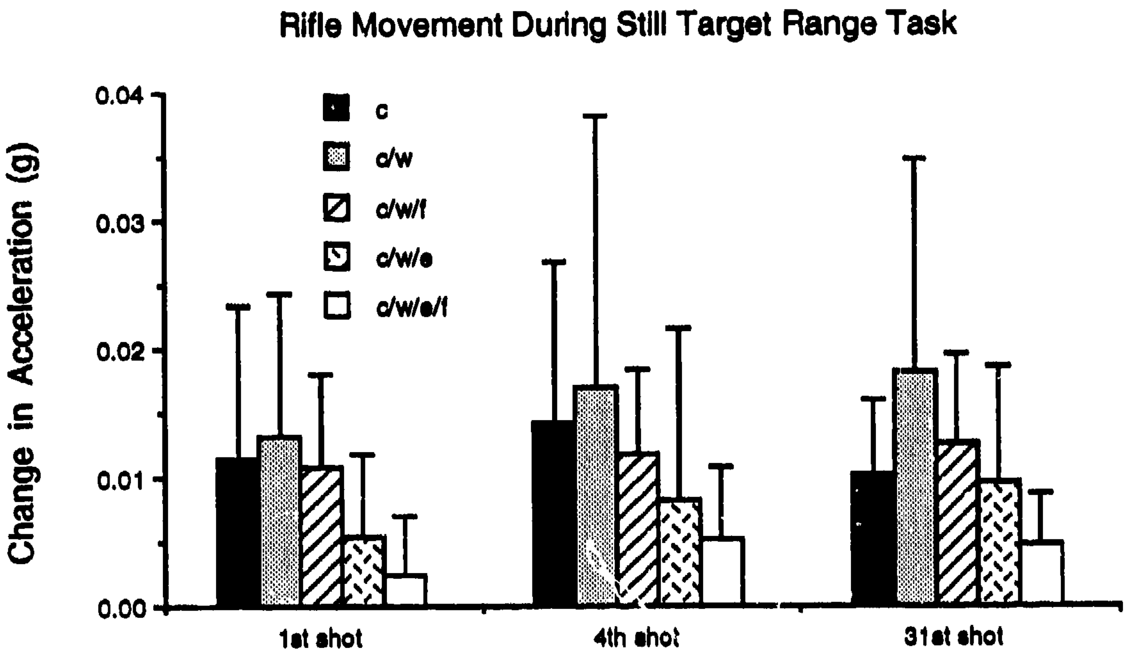

Figure 29. Acceleration of the rifle barrel during Rifle Range test expressed as changes from warm control condition.

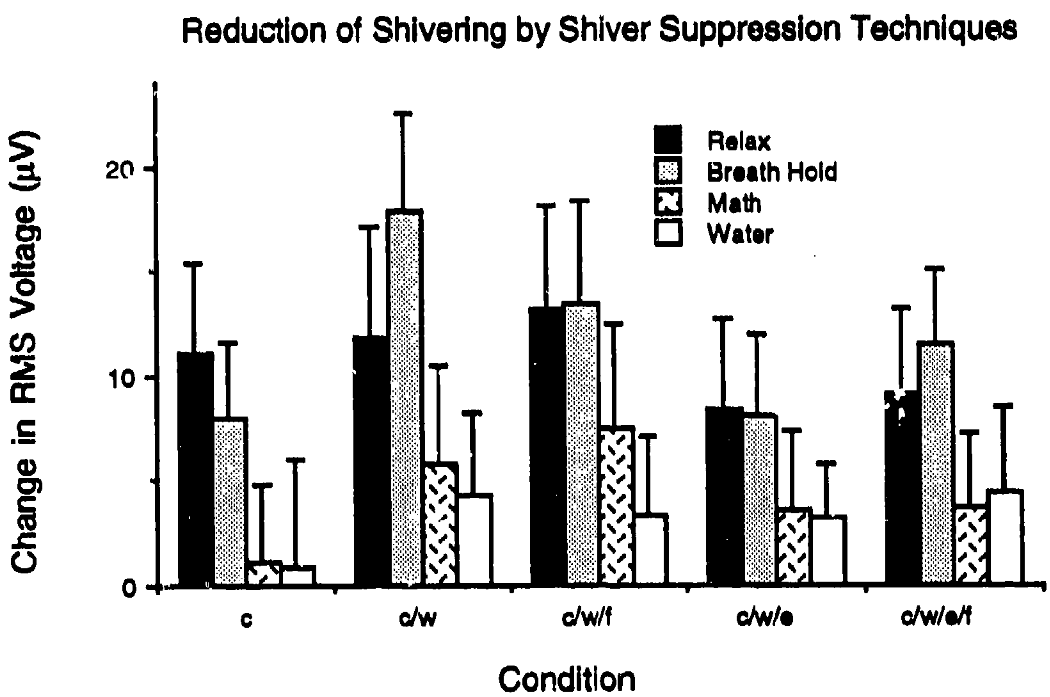

Figure 30. Change from control in RMS voltage with each shiver suppression method (means of all 7 muscles).

Shiver Suppression

The mean RMS value of all seven muscle groups, both control and post-maneuver, was computed for each subject in each condition and for each suppression maneuver. The control RMS value was subtracted from the post-maneuver RMS value to obtain the change in RMS induced by the suppression maneuver. The data for the mean of all seven muscles is presented in Figure 30. Note that in this presentation, the larger the value, the more effective the shiver suppression. In all conditions, the warm water ingestion was the least effective means of shiver suppression, and statistical analysis showed that there was no significant difference between the control and suppression period shiver RMS values for this shiver suppression maneuver. On the other hand, with relaxation, mental arithmetic and breath holding there was a significant difference (ANOVA $p \leq 0.05$) between the RMS values before and after these suppression maneuvers.

The shiver suppression results were analyzed for each individual muscle group across conditions as well (ANOVA). The data is summarized in Table 5. In Table 5, for each muscle and condition there is a 4 x 4 matrix; any non-zero entry indicates a shiver suppression technique that resulted in statistically significant ($p \leq 0.05$) suppression of shivering in that muscle group and condition.

Table 5. The effectiveness of shivering suppression techniques.

	Cond-1	Cond-2	Cond-3	Cond-4	Cond-5
Trapezius	R B	R B	R 0	R B	R B
	0 0	0 0	0 0	0 0	0 0
Pectoralis	R B	0 0	R B	R B	R B
major	M 0	0 0	M 0	0 0	0 0
Biceps	R 0	0 0	0 0	0 0	0 0
	0 0	0 0	0 0	0 0	0 0
Triceps	0 0	0 0	0 0	0 0	0 0
	M 0	0 0	0 0	M 0	0 0
Rectus	0 0	R 0	0 B	0 0	0 B
femoris	0 0	0 0	0 0	0 0	0 0
Biceps	0 0	0 0	0 0	0 0	0 0
femoris	0 0	0 0	0 0	0 0	0 0
Soleus	0 0	0 0	0 0	0 0	0 0
	0 0	0 0	0 0	0 0	0 0

If in the 4x4 matrix under any given condition and muscle group a letter other than 0 appears it indicates that the suppression technique (see abbreviations below) significantly suppressed the shivering ($p \leq 0.05$).
R = Relaxation, **B** = Breath Holding, **M** = Mental Arithmetic **W** = Warm Water Ingestion.

Of the 140 possible combinations of shivering suppression, muscle group and condition, there were 25 combinations that demonstrated a significant suppression of the shivering. Warm water ingestion produced no significant decrease in shivering in any muscle group or condition. Relaxation was responsible for significant suppression in 11 cases, breath holding 10 cases, and mental arithmetic 4 cases. Most of the successful shiver suppressions occurred in the trapezius, pectoralis major and triceps muscles (19 significant suppressions).

Discussion

Maintenance of Core Temperature:

Under control conditions of 21°C (warm protocol), without added stressors of cold water, exercise, or fatigue, mean core temperatures decreased by approximately 0.2°C over the first hour and remained relatively constant during the second half of the protocol (Figure 5). During the first 60 minutes of the warm protocol the activity level was minimal. Because of this, heat production generated by general motor activity could be considered below normal, therefore subjects' core temperatures decreased slightly. During the second half of the protocol, there was more (but not excessive) motor activity associated with performance evaluations and in the warm condition this appears to be sufficient to stabilize the core temperature.

The addition of the cold stress (0°C) alters the core temperature profile in a manner contrary to that which may have been expected. Rather than causing a greater decrease in core temperature, mean rectal temperatures in fact rose for approximately 45 minutes before starting to decline (Figure 5). The exposure to cold results in two physiological responses, (a) a peripheral vasoconstriction, limiting heat loss, and (b) the onset of shivering which generates heat.(2,9) These apparently account for the higher temperatures during the first 100 minutes in the cold conditions, in contrast to the warm control where subjects exhibited no measurable shivering activity. Adding cold water as a stressor does not appear to have any meaningful effect on core temperatures, however the combination of cold, water, and fatigue results in higher temperatures than in the cold, cold/water, or warm conditions until 2 hours into exposure time (Figure 5). After 120 minutes of exposure there is no appreciable difference in core temperature between any of the 6 conditions.

In considering the combination of cold exposure, water exposure, and fatigue, the body's response to cold stress appears to be amplified, which serves to preserve the core temperature more effectively (actually increasing the core temperature slighuy) than in the other non-exercise conditions.

In the two protocols including exercise (c/w/e and c/w/e/f) the core temperature increased significantly during the first hour of cold exposure. The maximum increase in core temperature was approximately 0.6°C, 10 -15 minutes after exercising ceased. At this point, the core temperature began to fall, reaching a level equal to all other conditions at about 130 minutes into the experiment (Figure 5). Moderate exercise during cold exposure may therefore act to increase or maintain core temperature but the benefits disappear shortly (approximately 1 hour) after the exercise is terminated. It would be of interest to re-evaluate

exercise and cold exposure with a protocol that spaces short "bursts" of moderate exercise over a longer cold exposure to assess whether this regimen could more effectively maintain core temperatures over a longer period of time.

Skin Temperature Response to Cold Exposure:

Mean skin temperature decreased slightly in the warm conditions. This is consistent with the fact that the subjects' core temperatures were decreasing and peripheral vasoconstriction was activated as a mechanism to conserve heat. In the protocols including cold exposure, the mean skin temperature decreased 5°C (Figure 6). There were no significant differences between conditions, however a slight increase in mean skin temperature can be observed in the two protocols that included exercise (c/w/e and c/w/e/f). The exercise bouts apparently stimulated some peripheral vasodilation to facilitate heat dissipation from the core to the periphery, even in the face of cold exposure.

Perception of Temperature and Comfort:

How the subjects felt overall and how they perceived their temperature was best correlated with their skin temperature (Figure 7). This perception was not reflected in the subject's core temperature and had no significant correlation to added stressors, i.e. water and fatigue. Note that even when the core temperature was increased by exercise in conditions 4 and 5, there was no significant improvement in perceived comfort or body temperature.

Performance as assessed by the Firearms Training System (F.A.T.S.).

Rifle Shooting Performance:

A number of different shooting scenarios were employed in an attempt to evaluate the effect of cold exposure alone and the effects of cold in conjunction with additional stressors. In conditions in which a stationary target was presented and shot groupings were evaluated as a measure of accuracy and consistency, (Materials & Methods, Rifle Range Course, p. 10) cold exposure resulted in a significant decrement in performance (Figure 8). The addition of other stressors (exercise, cold water and fatigue) did not increase the performance decrement. In fact, the trend was toward control levels with the addition of more stressors, as evidenced by the c/w/e/f scores, which were almost identical to the control values. All other scenarios fall in between cold alone and control with only the cold/wet/fatigue design and the cold conditions resulting in significant differences from the warm control (Figure 8). Perhaps the addition of stressors increased vigilance by posing greater challenges for the subjects. Alternatively, the addition of exercise could be

considered a reduction in stress rather than an additional stress, since exercise increased the core temperature and reduced shivering to some extent.

In an attempt to increase the level of difficulty in the target system and assess alertness, a moving target course was employed (Materials & Methods, Moving Targets, p. 11). In this test, there were no significant differences in performance between the six experimental protocols. There was, however, a noticeable trend (10% change) toward reduction in performance in what could be considered the most stressful protocol (cold/wet/exercise/fatigue). In addition, under conditions which involved 2 or more stressors, subjects tended to be more accurate but fire fewer shots than in the warm and cold conditions (Figure 9). Again, perhaps with the addition of more stressors, the subjects perceived the additional challenge and concentrated on accuracy, but were not able to react fast enough to fire at all targets, or were distracted enough by the cold discomfort that they did not see some of the targets.

The "quick kill" course was utilized as a reference measurement of reaction speed and vigilanceover a prolonged period of time (Materials & Methods, Quick Kill, p. 11). Subjects fired more shots in the cold conditions, but did not hit any more or any fewer targets than in the warm condition. This decrease in overall accuracy contrasts with the moving target course, but the tasks were quite different. In the Quick Kill task, targets were presented in a much faster sequence and in much greater numbers to the point of being beyond the capability of even the best marksmen to hit all of the targets. This saturation or overload eliminated the possibility of taking more time to aim, as was possible in the Moving Targets scenario. Consequently, the percentage of shots that hit was significantly decreased in all of the cold conditions except c/w (Figure 10). The similar reduction in all cold exposure conditions indicates that cold was the most detrimental factor in this type of evaluation, and that the other stressors had little or no effect.

Motor & Cognitive function:

In order to evaluate the effect of cold and added stressors upon the combination of motor performance and thought processes (decision making), the subjects were exposed to a number of judgmental shooting scenarios (Materials & Methods, Judgmental Shooting, p.11). While cold exposure appeared to be the greatest factor in the aforementioned tasks, cold exposure alone did not significan.' · alter the subjects' judgment of when to use force (Figure 11). However, when other stressors were added the response of the subjects to the shoot/no-shoot decision was less accurate, *i.e.* the percentage of correct decisions decreased. The only exception to this observation was in the cold/wet/fatigue protocol. The addition of an exercise factor resulted in poorer judgment, and was especially noticeable

and was especially noticeable when combined with sleep deprivation. This could be due to an overall fatigue factor (these scenarios take place after 100 minutes of exposure).

The Judgmental Shooting scenarios were also used to obtain a measurement of reaction time. Reaction time was calculated from the time that a significant threat warranting the use of deadly force was observable to the firing of the first shot. Since there was no significant difference in the subjects' reaction times to the shoot/no-shoot scenarios between conditions (Figure 12), the increase in incorrect decisions observed in some experiments could not be attributed to alterations in reaction times or perception of threats. The c/w/e/f condition (with the worst judgment performance) showed a tendency toward the slowest reaction times. The quickest reaction times occurred during the cold condition with correct decisions comparable with those seen in the warm condition. The addition of both wet clothing (water) and fatigue tended to have a negative additive effect on reaction time. Perhaps cold exposure alone resulted in an increase in arousal, resulting in faster reaction times as reported in other studies (22, 23).

Performance as assessed by non-shooting methods

Motor Function:

Grip strength was measured prior to and during cold exposure. In all conditions, excluding the warm control, grip strength decreased significantly when compared to the pre-exposure control levels (Figure 13). However, there were no significant differences between the cold conditions when compared with each other. Although the c/w condition (only the legs were exposed to water, grip strength was measured in the hand) resulted in the lowest value, as additional stressors were added the grip strength increased toward the warm control value (Figure 13). Although the heat generated by exercise could be proposed to account for this in the two exercise conditions, in the c/w/f and c/w/e/f conditions fatigue appeared to have an additional positive effect for unknown reasons.

The O'Connor Tweezer Dexterity Test (Figure 14) indicated that cold is the most detrimental stressor to fine dexterity. Other additional stressors had no effect on number of pegs placed. Similar results were obtained for the Grooved Pegboard test with the exception of a slight trend toward slower performance with added stressors.

Cognitive Assessment:

Employing the Complex Cognitive Assessment Battery (CCAB), cognitive function was estimated by computing the total score of the six sub-tests used (Figure 16). The total score was used for evaluation since none of the six sub-tests, when analyzed separately across conditions, showed any significant differences. Conditions c/w, c/w/f, and c/w/e

had total CCAB scores that were significantly lower than both the warm condition and the c/w/e/f condition.

The lowest CCAB score occurred in the c/w/f condition where it might be expected. The interesting result occurs when you add a small exercise component. The combination of all stressors (c/w/e/f), resulted in the highest CCAB score (Figure 16), which was not significantly different from the warm control. Therefore, even a small amount of exercise added to the other stressors may act to improve cognitive functioning during cold exposure.

Cardiovascular and Respiratory Responses:

The cardiovascular responses to all cold stress protocols were unremarkable. No abnormal rhythms were observed in any of the conditions. Only minimal increases in heart rate and blood pressure were observed (Figures 17 - 19) with the exception of the two protocols with an exercise component. In these two protocols containing exercise (c/w/e and c/w/e/f) the maximum increase in heart rate was approximately 75% (Figure 17) during each exercise bout. There was no significant difference in the increase in heart rate between the two conditions. Heart rates did not quite return to non-exercise levels between the two exercise bouts, but did so shortly after the end of the second exercise session (Figure 17).

Blood pressure changes in the two conditions with exercise (c/w/e and c/w/e/f) showed a 40% increase in systolic pressure (Figure 18) during all exercise bouts with no significant difference between the two conditions. In all the conditions, diastolic blood pressure remained constant or increased slightly with no significant differences across conditions or as a function of time within conditions (Figure 19).

During the first hour of cold exposure in conditions without exercise, the minute ventilation (V_E) increased by a factor of two (Figure 20). Note that minute ventilation, respiratory rate, and carbon dioxide production remained constant over the entire test period in the warm condition. The increase in minute ventilation associated with cold exposure was due to an elevation in tidal volume because the respiratory rates did not change. This physiological adjustment of increased tidal volume without change in breathing frequency augments alveolar ventilation while minimizing flow velocity work (32).

At the exercise periods in conditions c/w/e and c/w/e/f, both minute ventilation and respiratory rate increased dramatically with the minute ventilation increasing from 15 to 60 L/min and the respiratory rate increasing from 15 to 25 breaths/minute. Both parameters decreased to match the other cold exposure conditions shortly after conclusion of exercise (Figures 20 and 21).

The augmentation of the subject's metabolic system in response to cold exposure is reflected in the carbon dioxide production as a function of time. During the first hour of

cold exposure the carbon dioxide production increases slowly to a value approximately twice that of the pre-exposure level (Figure 22). After the 60 minute point, the carbon dioxide production plateaus for the remainder of the cold exposure. In the conditions with exercise (c/w/e and c/w/e/f) the metabolic increase (as indicated by elevation in carbon dioxide production) was equivalent and represented a 5 fold increase from 0.5 L/min to 2.5 L/min. Following the exercise bouts carbon dioxide production returned to levels observed in the other cold exposure groups.

Shivering in response to cold and added stressors

In response to all cold wet conditions the subjects developed measurable shivering by 12 minutes into the exposure. Two methods of data analysis were employed to estimate the magnitude of shivering:

(a) The RMS voltage of the EMGs were averaged for the seven muscle groups monitored for each condition. The mean RMS values were computed at 12 minute intervals during the first hour of exposure and at 100, 125 and 145 minutes of hour two (Figure 23). This method gives a picture of the overall shivering activity taking place.

(b) The data for all seven muscle groups is presented separately for each condition (Figures 24-28). By examining the activity levels of these muscle groups, we were able to determine which areas of the body are most active in regard to shivering.

In considering the mean RMS values for the five cold exposure conditions, the patterns of changing intensity of shivering can (arguably) be divided into three groups: (a) cold alone (condition 1), (b) cold + exercise (c/w/e, c/w/e/f), and (c) cold + water exposure (c/w, c/w/f). In the cold alone condition (a), the magnitude of shivering at onset was less than for all other conditions but did increase steadily during the first hour of exposure. The peak value of RMS was reached at 100 minutes followed by a modest decrease during the remainder of the exposure (Figure 23). Note that during the second hour the rectal temperatures in this condition were relatively stable. These observations may indicate that the subject, without any additional stressors, is settling (temporarily) into a new steady state of heat balance.

When exercise is added to the protocol (b above) the picture is altered dramatically. Prior to the onset of exercise the magnitude of shivering was not significantly different from the other cold exposure conditions. With the addition of exercise the shivering activity is significantly depressed. The shivering activity during the exercise bouts at 24 and 48 minutes into the protocol could not be measured due to the overriding EMG activity of

muscle contraction. However, at the 36 minute point, (between exercise bouts) the magnitude of shivering as estimated by the mean RMS values was considerably less than in the other three conditions (Figure 23). This same pattern of decreased or suppressed shiver activity is observed at the 60 minute point (i.e. 12 minutes past the second exercise bout). By 100 minutes into the cold exposure, shivering activity is the same under all conditions; the effect of exercise is lost. The addition of the exercise was apparently sufficient to raise core temperature (Figure 5) to a point where shivering was no longer needed to produce additional heat for its maintenance. This effect was of such a magnitude as to suppress shivering at least 12 minutes after the last exercise period, but had no long term effects on shivering or core temperature.

When the experimental condition included cold water exposure in addition to cold air but without exercise (c above), shivering (as estimated by the mean RMS voltage), occurred at higher intensity at the onset, and remained equal to or greater than that in cold air exposure alone. Throughout the exposure period the intensity of shivering increased progressively. This response was more apparent in the c/w exposure and somewhat less evident in the c/w/f exposure (Figure 23).

The rectal temperature profile in the wet protocols was not significantly different from the cold air alone exposure. The addition of cold water exposure does to some extent increase heat loss due to increased conductivity and evaporation. However, increased peripheral vasoconstriction of the cold water exposed extremities may somewhat limit heat loss. Along with this, the increase in shivering intensity associated with the cold water exposure apparently produced more heat, resulting in the maintenance of core temperature.

When the intensity of shivering was analyzed separately for each of the seven muscle groups, it became evident that the trapezius muscle group was the most active under all conditions (Figures 24-28). In most cases the shivering activity of the trapezius was at least twic (and sometimes three times) that of the other muscle groups (Figures 26-27). The other six muscle groups exhibited similar magnitudes of shivering within a condition and even between conditions. The differences between conditions, as well as the changes over time were dominated by the shivering activity of the trapezius.

The next most consistent muscle group in both magnitude and pattern within a condition and over time was the pectoralis major. It was felt that estimations of overall shivering intensity could therfore be best accomplished by monitoring the pectoralis major and the trapezius. This would make future experimentation and data analysis more efficient.

Rifle movement associated with shivering

Muscle activity associated with shivering was expected to decrease the stability of the rifle during shooting. In order to evaluate barrel movement, data from an accelerometer was analyzed in a manner similar to the EMGs, resulting in RMS voltages. In all cold conditions there were no significant increases in rifle movement when compared to control, and no significant difference between the points analyzed in the shooting scenario (Figure 29). The concentration inherent in the task of shooting (which involves breath holding and mental concentration as well as relaxation), may in itself depress shivering and tend to minimize alterations in rifle movement.

Shiver suppression

During the last 15 minutes of cold exposure the subjects attempted to suppress shivering by one of four methods: relaxation, breath holding, mental arithmetic, and warm water ingestion. Estimating the effectiveness of these four suppression methods by calculating the mean EMG-RMS of the seven muscle groups indicated that relaxation and breath holding were the most effective methods of suppression. On the other hand, warm water ingestion did not significantly suppress shivering in any of the conditions. Mental arithmetic was an effective suppression of shivering in the c/w/f condition only.

The effectiveness of suppression techniques on the seven individual muscle groups was evaluated across conditions (Table 5). Note that water ingestion had no significant suppression effect on any muscle group in any condition. Of the 140 attempts to suppress shivering, relaxation was significantly effective in 11 cases, breath holding in 10 cases, and mental arithmetic in 4 (a total of 25 successful suppressions). This apparently low success rate is due in large part to the low levels of activity found in the majority of the muscles. In the trapezius and pectoralis muscles, relaxation was effective in 9 of 10 cases; breath hold in 8 of 10 and mental arithmetic in 2 of 10. Because of its dominance in activity level, and thus potential for suppression of activity, the trapezius results reflect those seen in the evaluation of the overall activity consisting of the mean of all 7 muscles.

As indicated above, the suppression techniques were more effective in the muscles of the arm and shoulder (trapezius and pectoralis major) across all conditions. There was no significant suppression of shiver in the leg muscles (soleus and biceps femoris). The leg muscles are also those that show the lowest intensity of shivering (Figures 24-28). This may be due in part to the fact that the leg muscles are under tonic contraction in order to maintain the subject's upright (standing) position. Taken as a whole, the results of these shiver suppression experiments are consistent with previous work by other investigators (11,12,13,14).

Summary:

In summary, cold exposure was determined to be the most significant factor in reducing performance, causing significant reductions ($p \leq 0.05$) in skin temperature, rectal temperature, temperature perceptions, shooting performance, grip strength, and dexterity, both alone or when combined with any or all other factors. Addition of other stressors generally resulted in no greater physical performance decrements. To the contrary, in many cases, the addition of other stressors resulted in an improvement in performance over the cold condition (reduction in the decrement caused by cold). Perhaps the addition of stressors increased vigilance by posing greater challenges for the subjects. Alternatively, the addition of exercise could be considered a reduction in stress rather than an additional stress, since exercise increased the core temperature and reduced shivering to some extent.

Cognitive performance, however showed a different pattern. Cold exposure alone did not significantly alter the subjects' judgment of when to use force (Figure 11). However, when other stressors were added the response of the subjects to the shoot/no-shoot decisions were less accurate. Cognitive performance on the CCAB was highest in the c/w/e/f, control, and c conditions, with the aggregate overall scores in the c/w, c/w/f and c/w/e conditions significantly lower than control and c/w/e/f.

Shivering gradually increased throughout exposure in cold conditions but was delayed in conditions which included exercise, due to the rectal temperatures increased during exercise. The trapezius muscle showed considerably more shivering activity than any of the other muscles monitored. Shivering was significantly suppressed by relaxation, breath holding and mental arithmetic techniques but not by warm water ingestion.

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MISSING DATA:

Missing data due to technical problems are represented by blanks in the data tables.

SUBJECT IDENTIFIERS:

There were 2 conventions used for identifying subjects in the data tables.

(a) Subjects were assigned a number based on the order of their first experiment. Two subjects (numbers 2 & 7) voluntarily withdrew from the study, thus the numbering is 1 - 15 with subjects 2 & 7 deleted.

OR:

(b) Subjects completing the series of experiments were numbered 1 - 13 based on the order of their first experiment. In these cases subject 2 = subject 3 in (a) etc.

Appendix I

Consent Form

Project title: Studies of neural and cognitive function in subjects exposed to the cold marine-air interface, Phase I.

Investigators: L. E. Wittmers and R. G. Hoffman

You are invited to participate in a study evaluating the effects of various stressful situations associated with a cold environment on human physiological and psychological performance. All studies will take place in the environmental chamber at the Hypothermia Laboratory - University of Minnesota Duluth. The project is under the direction of Drs L. Wittmers and R. Hoffman.

In order to participate in this project you will be prescreened to determine if you are physically fit and whether or not you fit the body type criteria necessary to participate. We will require a short medical history and a 12 lead resting electrocardiogram, interpreted by the staff of the Clinical Science Department. If the electrocardiogram is normal you will be given a stress test. This will include walking (3 mph) on a treadmill with the grade increased at the rate of 2% up to a maximum of 18%. You will be considered as a candidate for participation if your heart rate does not exceed 90% of the predicted maximum (for your age and sex) at 18% grade. You will not be allowed to participate in these experiments if you are taking prescription or non-prescription medications.

If you pass the prescreening above, you will be requested to participate in five experimental situations each lasting no longer than 3 hours.

(1) Cold air - Cold water: You will be exposed to an ambient air temperature of 30° F and your legs will be wet up to the knees in 50° F water.

(2) Cold air - Cold water - Sleep deprivation: You will be exposed to an ambient air temperature of 30° F and your legs will be wet up to the knees in 50° F water. The sleep deprivation will be for 24 hours preceding the experiment.

(3) Cold air - Cold water - exercise: You will be exposed to an ambient air temperature of 30° F and your legs will be wet up to the knees in 50° F water. The exercise will consist of walking and step climbing to a heart rate of 70% of your predicted maximum.

(4) Cold air - Cold water - Exercise - Sleep deprivation: You will be exposed to an ambient air temperature of 30° F and your legs will be wet up to the knees in 50° F water. The exercise will consist of walking and step climbing to a heart rate of 70% of your predicted maximum. The sleep deprivation will be for 24 hours preceding the experiment.

(5) Cold air alone. You will be exposed to an ambient air temperature of 30° F.

These protocols are designed to answer the following question (a) which of the various environmental-stress scenarios is the one that causes the greatest rate of rectal temperature fall, earliest onset of shiver and the greatest decrement in physiological and psychological performance, and (b) which muscles contribute the most to overall body oscillation during shiver and consequently the greatest decrement in performance.

During the experiment you will be asked to perform certain mental and physical tasks to evaluate performance. Each task and its meaning will be explained to you by one of the project directors. In order to monitor physiological changes you will be instrumented with temperature sensors (rectal thermistor and three skin surface thermistor probes - face, toe and finger). Surface doppler probes will be applied at intervals to measure blood flow. Electromyographic electrodes will be applied over selected skeletal muscle groups to evaluate shiver. At intervals you will be required to breathe into a mouthpiece for measurements of metabolic rate. You will be required to give a blood and urine specimen before, during and after completion of each experiment. The urine samples will be analyzed for catecholamines to assess the magnitude of stress and the blood will be analyzed for enzymes to evaluate the intensity of shiver. The total amount of the blood sample taken will be less than 50 ml (1.7 ozs) per experiment. A minimum of 72 hours will elapse between each experiment.

You will be paid $100 for each experimental condition for a total of $500. The payment will be made at the end of the five conditions or you will be paid the appropriate fraction of $500 if you choose to withdraw from the project.

From our experience we expect that the protocols described above will cause only moderate discomfort. There will be some tiredness and fatigue associated with both the sleep deprivation and exercise aspects of the study. Exposure to cold will result in an increase in heart rate and blood pressure. There are potential risks of abnormal heart beats, however at the temperatures you will be exposed to these are extremely rare. You will be continuously monitored to allow us to minimize any risk. Cold exposure can cause tissue damage by freezing. You will have sufficient protective clothing to avert this tissue damage and your rectal and skin temperatures will be continuously monitored. There may be some mild discomfort in placing the rectal thermistor and having it in place while participating in the experiment. If you have any problems, please notify one of the project directors immediately.

Safety assurance is the responsibility of the project directors. There will be a physician on call in the building during the entire exposure period in the event of a medical injury.

Any subject can terminate his/her involvement at any time without affecting their relationship with the University of Minnesota, Duluth or the U. S. Navy (the agency supporting this program). The benefits to be expected will be that we will gain more insight into how these cold-stress environments alter human physiological and psychological functioning.

Any information obtained in connection with this study that can be identified with you will remain confidential and will be disclosed only with your permission. In any written reports or publications, no one will be identified or identifiable and only aggregate data will be presented. A representative of the U. S. Naval Medical Research and Development Command may inspect the records of this research but confidentiality will be preserved.

Your decision whether or not to participate will not affect your future relations with the University of Minnesota, Duluth School of Medicine or the U. S. Navy in any way. If you decide to participate you are free to discontinue participation at any time without affecting such relationships.

You are authorized all necessary medical care for injury or disease which is the proximate result of your participation in this research. (If you receive an injury or contract a disease as a direct result of your participation in this project all medical expenses will be the responsibility of the research project.)

If you have questions about the research, please call Dr. L. E. Wittmers, 726-8551 or the other project director. If you have questions about the research subjects' rights or wish to report a research-related injury please call Dr. Ronald Franks, Dean, University of Minnesota, Duluth School of Medicine, Duluth, MN, 55812 (218-726-7571).

You will be offered a copy of this form to keep.

You are making a decision whether or not to participate. Your signature indicates that you have read the information provided above and have decided to participate. You may withdraw at any time without prejudice after signing this form.

Signature ______________________ Date ______________

Signature of Witness ______________________ Signature of Investigator ______________________

Cold Stress Subject Instruction Sheet

The following is a list of things we would like you to do before your arrival at the hypothermia laboratory.

1. No drug use 48 hours prior to any experiment.

2. No alcohol use 24 hours prior to any experiment.

3. No caffeine or tobacco use 12 hours prior to any experiment.

4. A normal nights sleep the night before each experiment. (unless you are schedule for a sleep deprivation protocol). For the sleep deprivation studies, specific directions will be given.

5. Eat a light meal 2 hours prior to your arrival at the hypothermia laboratory.

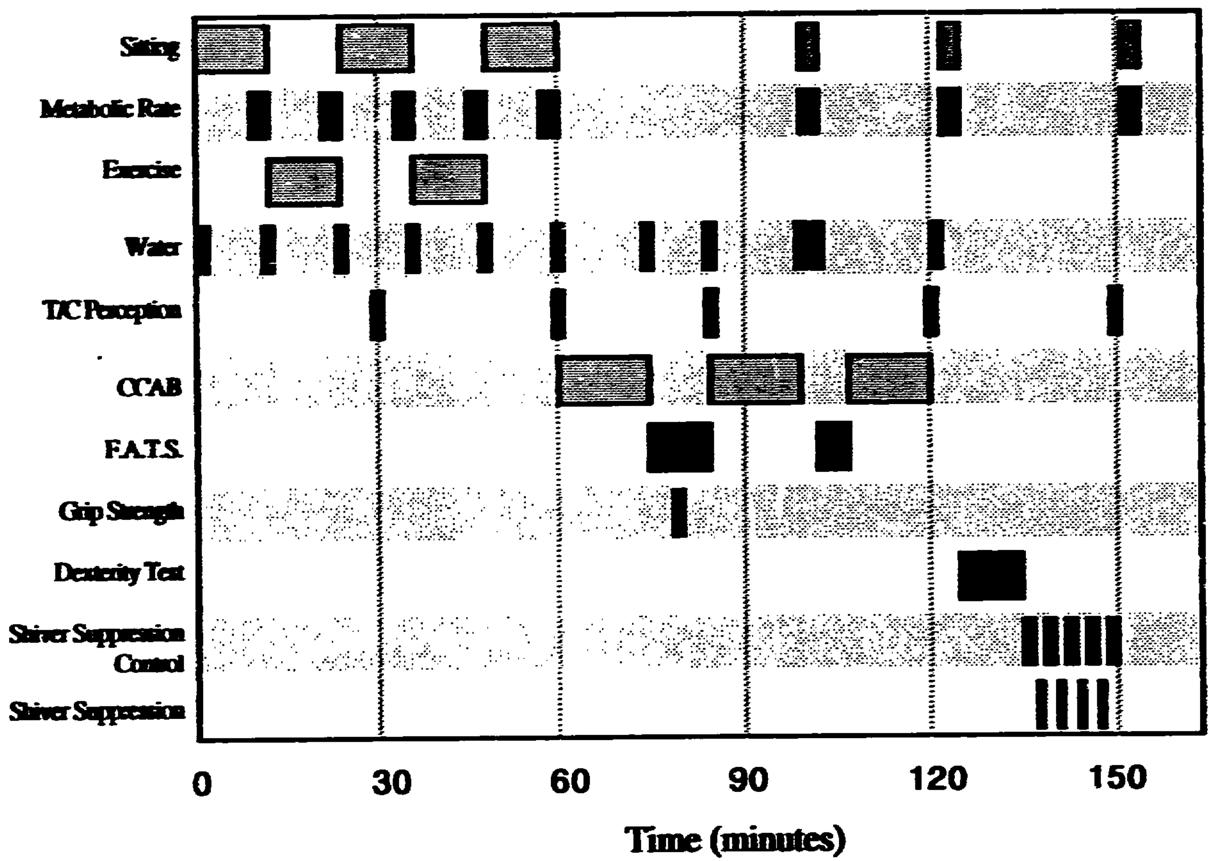
6. Besides the clothing you will have on when you arrive, please bring an extra pair of cotton socks and a pair of gym/running shorts. All other clothing that you will wear during the experiments (pants, belt, shirt and boots) will be provided by us.

7. A pretest urine sample will be required. Empty your bladder completely about 1 hour prior to arrriving at the hypothermia laboratory. <u>Note and record the exact time</u> and give that information to one of the investigators.

Sleep Deprivation Protocol (Not included as a part of the general instructions.)

Do not sleep during the 24 hours prior to your scheduled experimental time.

Figure 1a. Gantt Chart Describing Protocols Including Water and Exercise.
(c/w/e & c/w/e/f)



This chart and those following, illustrate the details of the various protocols. There was some overlap in the designs because the fatigue factor did not play a role in the sequencing of tasks during experiments. In addition, the cold and warm conditions were duplicates of each other except for the ambient temperature.

Figure 1b. Gantt Chart Describing Protocols Including Water but <u>without</u> Exercise.
(c/w & c/w/f)

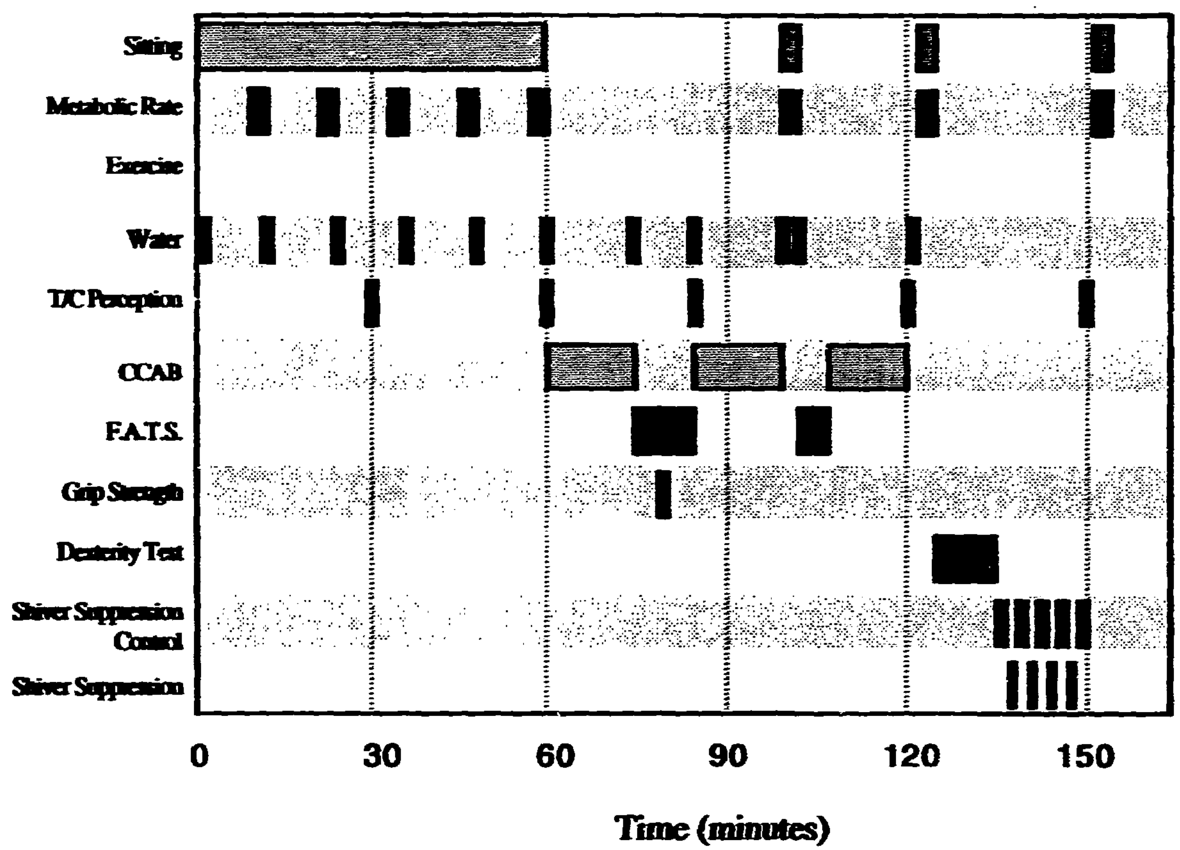


Figure 1c. Gantt Chart Describing Cold and Warm Protocols <u>without</u> Water or Exercise.
(c & warm)

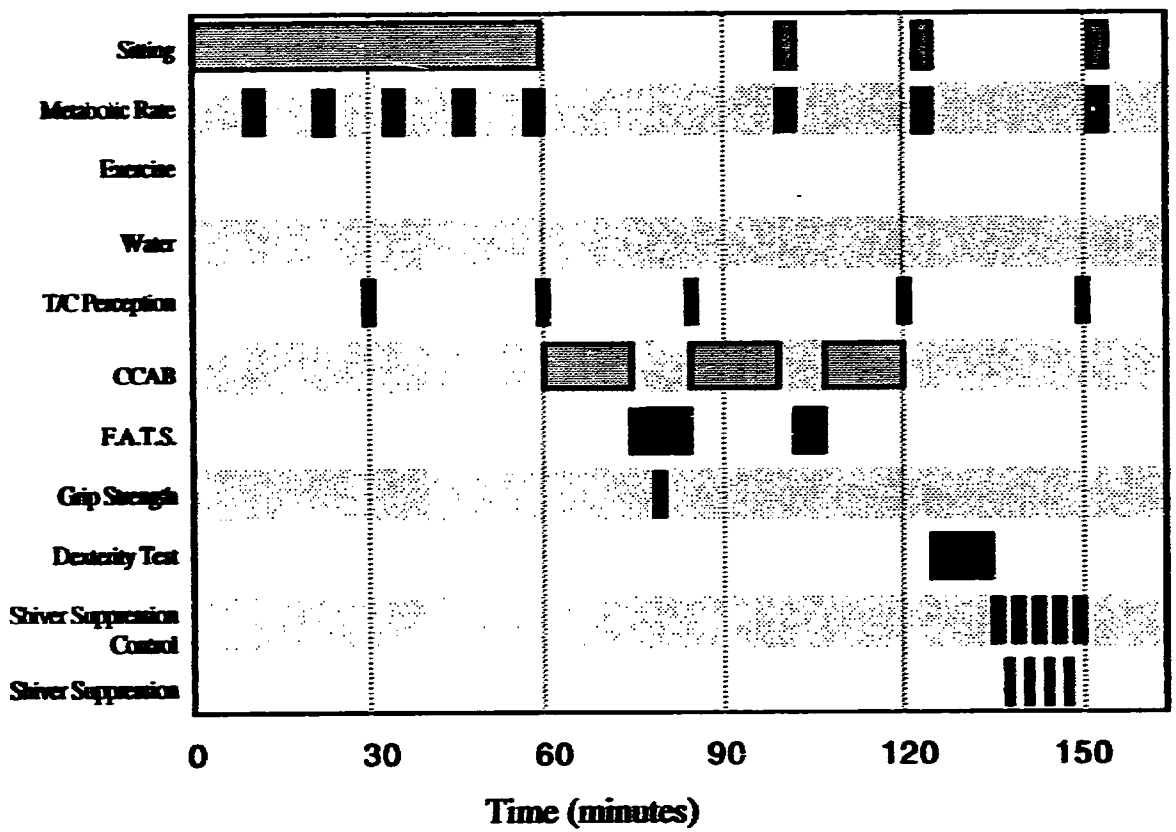


Table 1
Rectal Temperatures (°C)
Condition 1 (Cold)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	37.7	37.6	37.5	37.4	37.6	37.5	37.2	37.8	37.0	37.5	37.3	38.0	37.7	37.5
5	37.7	37.7	37.6	37.3	37.6	37.5	37.2	38.1	37.1	37.5	37.4	38.1	37.9	37.6
15	37.7	37.7	37.5	37.2	37.6	37.5	37.4	38.1	37.2	37.6	37.5	38.0	37.9	37.6
25	37.6	37.6	37.4	37.2	37.5	37.5	37.4	38.1	37.2	38.1	37.5	38.1	37.9	37.6
35	37.4	37.7	37.3	37.3	37.5	37.5	37.5	38.0	37.3	38.2	37.4	38.0	37.8	37.6
45	37.4	37.8	37.1	37.3	37.5	37.4	37.5	37.9	37.3	38.4	37.3	37.9	37.7	37.6
55	37.2	37.9	37.0	37.4	37.4	37.4	37.5	37.8	37.2	38.5	37.2	37.9	37.6	37.5
65	37.0	37.8	36.8	37.4	37.4	37.3	37.4	37.6	37.0	38.2	37.2	37.8	37.3	37.4
75	36.9	37.8	36.9	37.4	37.4	37.3	37.4	37.5	36.9	38.0	37.2	37.8	37.1	37.4
85	36.8	37.6	37.0	37.4	37.3	37.2	37.3	37.3	36.9	37.8	37.1	37.8	36.9	37.3
95	36.8	37.7	37.2	37.3	37.2	37.2	37.2	37.3	36.8	37.8	37.1	37.8	36.9	37.2
105	36.8	37.8	37.1	37.2	37.1	37.0	37.2	37.3	36.9	37.7	37.1	37.8	36.9	37.2
115	36.8	37.9	37.2	37.2	37.1	37.2	37.2	37.3	36.9	37.7	37.1	37.8	36.8	37.2
120	36.9	37.9	37.3	37.1	37.1	37.3	37.2	37.3	36.9	37.7	37.1	37.8	36.9	37.3
125	36.9	37.9	37.3	37.2	37.1	37.3	37.2	37.4	36.8	37.8	37.2	37.9	36.9	37.3
135	36.9	37.9	37.4	37.2	37.1	37.3	37.3	37.3	36.8	37.8	37.1	37.8	36.9	37.3

Table 2
Rectal Temperatures (°C)
Condition 2 (Cold, Wet)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	37.6	37.3	37.5	37.4	37.5	37.3	37.1	38.1	36.8	37.4	33.8	37.8	37.8	37.2
5	37.6	37.3	37.7	37.3	37.6	37.4	37.1	38.1	36.9	37.5	37.5	37.9	37.9	37.5
15	37.7	37.4	37.7	37.4	37.7	37.5	37.2	38.1	37.0	37.5	37.5	38.0	37.8	37.6
25	37.7	37.4	37.7	37.4	37.7	37.5	37.2	38.1	37.1	37.6	37.6	38.0	37.8	37.6
35	37.6	37.3	37.5	37.4	37.8	37.5	37.3	38.1	37.2	37.6	37.6	38.0	37.7	37.6
45	37.4	37.4	37.5	37.4	37.7	37.5	37.4	38.0	37.2	37.7	37.6	38.0	37.6	37.6
55	37.2	37.5	37.4	37.4	37.6	37.5	37.5	37.9	37.1	37.6	37.5	37.9	37.5	37.5
65	37.2	37.5	37.3	37.4	37.4	37.3	37.4	37.7	36.9	37.5	37.3	37.8	37.3	37.4
75	37.1	37.5	37.5	37.4	37.3	37.2	37.5	37.6	36.8	37.5	37.3	37.7	37.3	37.4
85	37.0	37.6	37.4	37.4	37.2	37.1	37.5	37.5	36.7	37.4	37.2	37.6	37.2	37.3
95	36.9	37.8	37.4	37.2	37.2	36.9	37.4	37.4	36.7	37.5	37.1	37.6	37.2	37.3
105	36.9	37.8	37.1	37.2	37.2	36.9	37.4	37.4	36.8	37.5	37.2	37.6	37.2	37.2
115	37.0	37.8	37.2	37.1	37.2	36.9	37.4	37.3	36.7	37.5	37.2	37.7	37.2	37.2
120	37.0	37.9	37.2	37.1	37.3	37.0	37.5	37.4	36.8	37.5	37.2	37.7	37.3	37.3
125	36.9	37.9	37.1	37.1	37.2	37.0	37.5	37.4	36.7	37.6	37.4	37.7	37.3	37.3
135	37.0	37.9	37.3	37.1	37.1	37.1	37.5	37.4	36.7		37.3	37.7	37.3	37.3

Column numbers are the subject identifiers
Temperatures are 10 minute averages

Table 3
Rectal Temperatures (°C)
Condition 3 (Cold, Wet, Fatigue)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	37.7	37.7	37.6	37.4	37.6	37.7	37.9	*	36.9	30.0	37.3	38.1	37.5	37.0
5	37.6	37.7	37.6	37.3	37.7	37.6	37.5	*	37.1	37.8	37.3	38.2	37.5	37.6
15	37.7	37.8	37.6	37.4	37.7	37.7	38.1	*	37.1	37.8	37.3	38.2	37.6	37.7
25	37.6	37.7	37.7	37.4	38.0	37.7	38.1	*	37.1	37.8	37.3	38.1	37.5	37.7
35	37.5	37.7	37.7	37.4	38.0	37.7	38.2	38.2	37.2	37.9	37.5	38.0	37.5	37.7
45	37.5	37.7	37.7	37.4	38.2	37.7	38.2	38.2	37.2	37.9	37.4	37.9	37.4	37.7
55	37.4	37.8	37.7	37.4	38.3	37.7	38.2	38.2	37.1	37.9	37.4	37.8	37.3	37.7
65	37.3	37.8	37.6	37.4	38.2	37.5	38.1	38.1	36.9	37.7	37.2	37.7	37.2	37.6
75	37.3	37.9	37.7	37.4	38.1	37.4	38.0	38.0	36.8	37.7	37.2	37.7	37.2	37.6
85	37.1	37.8	37.6	37.4	37.6	37.3	37.8	37.9	36.7	37.6	37.0	37.6	37.1	37.4
95	37.0	37.9	37.6	37.2	37.3	37.2	37.7	37.7	36.8	37.6	37.0	37.6	37.2	37.4
105	37.0	38.0	37.6	37.2	37.2	37.2	37.9	37.5	36.9	37.6	36.9	37.6	37.2	37.4
115	36.9	37.9	37.6	37.1	36.9	37.1	37.9	37.4	36.8	37.6	36.9	37.5	37.2	37.3
120	37.0	38.0	37.5	37.1	36.8	37.2	37.9	37.2	36.9	37.6	36.9	37.4	37.2	37.3
125	37.0	38.0	37.5	37.1	36.8	37.2	38.0	37.2	36.9	37.7	37.0	37.4	37.2	37.3
135	36.9	38.0	37.5	37.1	36.7	37.2	38.0	37.2	36.9	37.7	37.1	37.4	37.2	37.3

Table 4
Rectal Temperatures (°C)
Condition 4 (Cold, Wet, Exercise)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	37.9	37.6	37.3	37.2	37.6	37.5	37.3	38.0	37.0	37.8	37.5	38.1	37.4	37.6
5	37.9	37.6	37.5	37.2	37.6	37.5	37.4	38.0	37.1	37.8	37.5	38.2	37.7	37.6
15	38.0	37.6	37.5	37.3	37.7	37.5	37.4	38.0	37.2	37.7	37.6	38.2	37.7	37.6
25	38.2	37.8	38.3	37.8	38.0	37.8	37.7	38.4	37.3	38.1	38.0	38.1	37.8	37.9
35	38.2	37.9	38.4	37.9	38.0	37.9	37.9	38.4	37.7	38.1	38.0	38.0	37.9	38.0
45	38.4	37.8	38.6	38.2	38.2	37.9	38.0	38.6	37.7	38.2	38.2	37.9	38.0	38.1
55	38.4	37.9	38.7	38.3	38.3	38.0	38.2	38.7	37.9	38.3	38.2	37.8	38.2	38.2
65	38.3	37.8	38.3	38.1	38.2	38.0	38.0	38.5	37.6	38.0	38.0	37.7	38.0	38.0
75	38.2	37.8	38.1	38.0	38.0	37.9	37.9	38.4	37.4	37.9	37.9	37.7	38.0	37.9
85	38.0	37.8	37.9	37.6	37.6	37.8	37.9	38.3	37.2	37.7	37.7	37.6	37.7	37.8
95	37.8	37.8	37.8	37.4	37.3	37.6	37.7	38.0	37.1	37.5	37.6	37.6	37.6	37.6
105	37.7	37.9	37.7	37.2	37.2	37.4	37.7	37.9	37.1	37.5	37.6	37.6	37.4	37.5
115	37.6	38.0	37.6	37.2	36.9	37.3	37.6	37.8	37.0	37.4	37.5	37.5	37.3	37.4
120	37.5	38.0	37.5	37.1	36.8	37.3	37.6	37.7	36.9	37.4	37.5	37.4	37.2	37.4
125	37.3	38.0	37.5	37.2	36.7	37.2	37.6	37.7	36.9	37.4	37.5	37.4	37.1	37.4
135	37.3	38.0	37.5	37.2	36.7	37.2	37.6	37.7	37.0	37.5	37.5	37.4	37.1	37.4

Column numbers are the subject identifiers
Temperatures are 10 minute averages

Table 5

Rectal Temperatures (°C)
Condition 5 (Cold, Wet, Exercise, Fatigue)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	37.6	37.5	37.8	37.6	37.4	37.2	37.2	37.8	36.9	37.5	37.2	37.7	37.7	37.5
5	37.6	37.6	37.9	37.6	37.5	37.2	37.3	37.8	37.0	37.5	37.3	37.8	37.6	37.5
15	37.5	37.5	37.9	37.6	37.4	37.3	37.3	37.9	37.2	37.6	37.3	37.8	37.7	37.5
25	37.8	37.8	38.5	38.1	37.9	37.6	37.7	38.2	37.7	38.1	37.8	38.0	37.8	37.9
35	38.1	37.8	38.6	38.2	38.0	37.8	37.8	38.2	37.8	38.2	37.9	38.2	37.9	38.0
45	38.1	37.9	38.8	38.3	38.3	38.0	37.9	38.4	37.9	38.4	38.1	38.3	37.9	38.2
55	38.1	38.0	38.9	38.4	38.3	38.1	37.9	38.3	38.0	38.5	38.3	38.5	37.9	38.3
65	37.9	37.9	38.4	38.2	38.1	38.0	37.8	38.1	37.8	38.2	38.0	38.4	37.7	38.0
75	37.8	37.9	38.1	38.1	38.0	37.9	37.7	37.9	37.5	38.0	37.9	38.4	37.6	37.9
85	37.5	37.8	37.8	38.0	37.8	37.7	37.6	37.8	37.3	37.8	37.8	38.3	37.4	37.7
95	37.4	37.8	37.6	37.8	37.4	37.5	37.5	37.6	37.3	37.8	37.6	38.2	37.2	37.6
105	37.3	37.8	37.6	37.7	37.2	37.3	37.4	37.5	37.2	37.7	37.3	38.0	37.1	37.5
115	37.1	37.8	37.6	37.6	37.1	37.1	37.4	37.3	37.2	37.7	37.1	37.9	37.1	37.4
120	37.0	37.8	37.6	37.6	37.0	36.8	37.3	37.3	37.1	37.7	37.1	37.8	37.1	37.3
125	36.9	37.8	37.6	37.7	36.9	36.6	37.3	37.3	37.1	37.8	37.1	37.7	37.1	37.3
135	36.9	37.9	37.7	37.7	36.9	36.5	37.3	37.3	37.0	37.8	37.1	37.6	37.1	37.3

Table 6

Rectal Temperatures (°C)
Condition 6 (Warm)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	39.0	37.7	37.6	37.3	37.3	37.7	37.3	38.1	36.8	38.0	37.0	37.9	38.3	37.6
5	38.0	37.8	37.5	37.4	37.4	37.7	37.3	38.1	36.9	38.1	36.9	37.9	38.2	37.6
15	38.0	37.7	37.5	37.3	37.5	37.7	37.2	38.0	37.0	38.1	36.7	37.8	38.1	37.6
25	37.9	37.6	37.4	37.2	37.5	37.7	37.2	37.9	37.0	38.0	36.7	37.8	38.0	37.5
35	37.8	37.6	37.4	37.1	37.5	37.7	37.1	37.8	37.0	37.9	36.6	37.7	38.0	37.5
45	37.8	37.5	37.2	37.0	37.4	37.7	37.1	37.7	37.0	37.8	36.5	37.6	37.9	37.4
55	37.7	37.4	37.2	36.9	37.3	37.6	37.0	37.6	36.9	37.8	36.5	37.5	37.8	37.3
65	37.7	37.4	37.1	36.8	37.2	37.5	36.8	37.6	36.9	37.6	36.6	37.4	37.7	37.3
75	37.6	37.5	37.2	36.9	37.2	37.5	36.9	37.7	36.9	37.6	36.6	37.4	37.7	37.3
85	37.6	37.5	37.2	36.9	37.1	37.4	37.0	37.6	36.8	37.6	36.7	37.4	37.6	37.3
95	37.5	37.5	37.4	36.9	37.1	37.4	37.0	37.6	36.9	37.6	36.8	37.4	37.6	37.3
105	37.6	37.5	37.3	36.9	37.1	37.4	37.0	37.6	36.9	37.6	36.8	37.5	37.7	37.3
115	37.6	37.5	37.3	36.8	37.0	37.5	36.9	37.6	36.9	37.6	36.8	37.5	37.6	37.3
120	37.6	37.4	37.4	36.8	37.1	37.4	37.0	37.6	37.0	37.6	36.9	37.5	37.6	37.3
125	37.6	37.5	37.4	36.9	37.2	37.5	37.0	37.6	37.0	37.7	37.0	37.4	37.6	37.3

Column numbers are the subject identifiers
Temperatures are 10 minute averages

Table 7
Mean Skin Temperatures (°C)
Condition 1 (Cold)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	33.5	32.4	33.5	30.9	30.7	32.5	32.7	31.6	33.1	33.4	32.1	33.7	32.6	32.5
5	32.1	31.3	32.2	30.2	29.4	31.2	31.0	30.8	31.9	31.2	31.0	32.2	31.5	31.2
15	30.7	30.3	31.0	28.8	27.8	29.9	29.3	29.5	30.1	29.0	29.9	30.2	29.8	29.7
25	29.7	29.7	30.5	28.3	27.6	28.9	28.1	28.8	29.3	29.0	29.4	29.0	28.6	29.0
35	29.4	29.3	29.7	28.1	27.3	28.3	27.2	28.7	28.8	28.4	28.9	28.3	27.8	28.5
45	28.9	28.9	29.1	28.0	26.7	27.9	26.6	28.3	28.4	27.9	28.5	27.7	27.0	28.0
55	28.6	28.5	28.6	28.2	26.5	27.6	26.2	28.0	28.0	27.7	28.1	27.1	26.6	27.7
65	28.5	28.3	28.3	26.4	26.3	27.0	25.9	27.4	27.6	27.7	28.2	26.1	26.8	27.3
75	28.5	28.7	26.3	26.6	26.0	27.0	26.1	27.6	27.7	27.8	28.6	26.1	27.2	27.4
85	29.0	29.8	29.1	26.9	25.7	27.4	26.4	28.1	28.2	27.8	29.1	27.0	27.7	27.9
95	29.4	30.1	29.1	27.0	25.7	27.5	26.5	28.3	28.2	27.6	29.3	27.4	27.9	28.0
105	29.2	29.7	29.1	27.1	25.7	27.3	26.4	28.0	28.2	27.7	29.2	27.2	28.1	27.9
115	29.1	29.7	29.2	26.5	25.6	27.4	26.3	27.9	28.2	27.7	29.4	27.1	28.2	27.9
120	29.0	29.5	29.0	26.5	25.5	27.3	26.1	27.3	28.1	27.6	29.3	26.7	28.1	27.7
125	28.9	29.7	28.9	26.0	25.2	27.5	25.9	27.4	28.1	27.7	28.7	26.7	28.1	27.6
135	28.8	29.6	28.9	25.9	24.9	27.4	25.9	27.7	27.9	27.4	28.6	27.0	28.0	27.5

Table 8
Mean Skin Temperatures (°C)
Condition 2 (Cold, Wet)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	33.3	33.7	33.5	32.4	31.8	32.8	32.0	33.4	31.9	32.9	33.3	33.5	33.3	32.9
5	31.7	32.7	31.3	29.1	30.5	30.5	30.2	31.6	30.4	31.1	32.1	32.0	31.8	31.2
15	29.0	31.7	30.2	28.9	28.8	27.7	28.9	29.9	29.6	29.1	30.8	30.2	30.4	29.6
25	27.8	31.3	29.1	29.1	27.7	26.4	27.9	29.0	29.0	28.2	30.1	29.1	29.6	28.8
35	27.0	30.8	28.7	28.8	27.3	25.8	26.9	28.3	28.5	27.7	29.5	28.1	28.9	28.2
45	29.1	30.8	28.0	28.6	27.0	25.4	26.3	27.9	28.1	27.1	29.0	27.5	28.7	28.0
55	28.1	30.9	27.8	28.3	26.8	25.1	26.0	27.5	27.8	26.7	28.7	27.1	28.6	27.6
65	26.8	30.6	27.8	28.1	26.9	24.8	25.9	26.8	27.2	26.8	28.3	26.6	28.9	27.3
75	28.4	30.9	27.5	28.2	26.3	24.9	25.8	26.8	27.3	27.2	28.3	26.8	29.0	27.5
85	28.7	31.2	28.2	28.7	26.3	25.1	25.8	27.5	27.5	27.2	28.9	27.7	29.3	27.8
95	29.3	31.1	28.3	28.4	26.5	25.4	25.9	27.5	28.2	27.4	29.0	27.8	29.5	28.0
105	29.2	30.7	27.8	27.9	26.4	25.3	25.6	27.2	28.1	27.5	28.9	27.9	29.5	27.8
115	28.9	30.6	27.9	27.8	26.3	25.1	25.8	27.1	28.0	27.6	29.1	27.9	29.6	27.8
120	29.1	30.2	27.9	27.7	25.6	25.3	25.8	26.8	27.6	27.3	29.1	27.3	28.7	27.6
125	28.7	30.1	27.2	27.4	26.0	25.3	26.1	26.7	27.4	27.4	29.0	27.3	29.3	27.5
135	28.6	30.0	28.1	27.6	26.2	25.2	25.9	26.6	27.7		29.1	27.6	29.4	27.7

Column numbers are the subject identifiers
Temperatures are 10 minute averages

Table 9

Mean Skin Temperatures (°C)
Condition 3 (Cold, Wet, Fatigue)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	32.9	34.7	33.8	32.4	32.2	32.4	31.5	*	33.2	32.1	33.0	30.2	33.2	32.6
5	31.7	32.8	32.5	29.1	30.6	31.1	30.2	*	31.2	30.4	32.0	30.0	31.7	31.1
15	29.9	31.7	31.7	28.9	28.1	29.3	29.3	*	30.2	29.1	30.9	28.7	29.7	29.8
25	28.5	30.9	31.1	29.1	28.1	28.4	28.5	*	29.4	27.3	30.4	27.6	28.4	29.0
35	28.2	30.1	30.8	28.8	27.0	27.8	27.7	32.5	28.7	27.7	30.0	27.0	27.8	28.8
45	28.0	29.8	30.5	28.6	26.7	27.3	27.3	31.0	28.6	26.9	29.7	26.4	27.5	28.3
55	27.7	29.4	30.3	28.3	27.1	27.0	26.7	30.2	28.5	26.5	29.2	26.2	27.3	28.0
65	28.1	29.0	29.3	28.1	27.0	26.4	26.6	29.3	28.4	26.2	28.6	27.1	27.2	27.8
75	28.2	29.1	29.0	28.2	26.7	26.3	26.5	28.4	28.2	26.3	28.7	27.4	27.5	27.7
85	28.8	29.7	29.8	28.7	26.2	26.3	26.9	27.4	28.3	26.8	29.0	27.1	28.1	27.9
95	28.7	29.6	29.6	28.4	26.3	26.4	26.9	26.9	28.5	26.8	29.0	27.5	28.1	27.9
105	28.9	29.2	29.5	27.9	25.9	26.1	26.9	26.7	28.6	26.7	29.1	27.2	28.3	27.8
115	28.6	29.3	29.2	27.8	25.7	26.4	26.8	27.2	28.4	26.6	29.1	26.7	28.2	27.7
120	28.6	29.0	28.9	27.7	25.0	26.2	26.6	27.6	28.1	26.9	28.9	26.3	28.0	27.5
125	28.8	28.9	29.3	27.4	25.4	26.6	26.6	27.6	28.4	27.0	28.8	27.3	27.8	27.7
135	28.4	28.7	29.1	27.6	25.5	26.6	26.5	25.8	28.2	26.8	29.0	27.2	27.9	27.5

Table 10

Mean Skin Temperatures (°C)
Condition 4 (Cold, Wet, Exercise)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	33.9	32.5	31.9	32.3	32.2	32.4	36.1	33.0	33.4	30.5	32.3	30.2	32.8	32.6
5	32.3	32.0	31.3	30.9	30.6	30.7	31.0	31.5	31.9	28.5	30.6	30.0	31.4	31.0
15	31.0	31.3	28.4	28.6	28.1	28.0	28.6	29.6	30.5	24.6	28.6	28.7	29.3	28.9
25	31.4	31.5	29.3	29.7	28.1	28.0	28.5	29.6	30.7	26.8	29.0	27.6	28.8	29.2
35	30.8	31.2	28.1	28.6	27.0	27.4	27.7	29.5	31.4	27.3	29.4	27.0	28.3	28.7
45	30.6	31.0	29.0	28.6	26.7	27.6	27.5	29.5	30.0	27.2	28.8	26.4	27.9	28.5
55	30.4	31.1	27.9	28.6	27.1	27.8	27.4	29.5	31.2	27.9	28.9	26.2	28.7	28.7
65	29.9	30.5	27.2	28.1	27.0	27.7	26.8	29.2	30.2	27.6	28.6	27.1	29.0	28.4
75	29.6	30.2	27.3	28.1	26.7	27.4	26.6	28.9	29.6	27.0	28.6	27.4	28.8	28.2
85	28.7	30.6	27.7	27.7	26.2	26.6	26.2	27.9	29.8	27.1	28.6	27.1	28.6	28.0
95	30.0	31.0	27.6	27.2	26.3	26.7	26.3	27.9	29.7	27.2	28.3	27.5	28.2	28.0
105	29.5	30.7	27.9	26.9	25.9	26.6	26.3	27.5	29.7	27.0	28.3	27.2	28.5	27.8
115	29.5	30.3	28.7	26.9	25.7	26.9	26.1	27.5	29.6	26.8	28.0	26.7	27.9	27.7
120	29.1	30.0	27.8	26.8	25.0	26.7	26.0	27.1	29.5	26.6	28.3	26.3	27.5	27.4
125	28.9	29.7	27.6	26.8	25.4	26.9	26.4	27.0	29.4	26.6	28.3	27.3	27.8	27.5
135	28.6	29.3	27.5	26.8	25.5	26.9	26.5	26.8	29.5	26.6	27.9	27.2	28.3	27.5

Column numbers are the subject identifiers
Temperatures are 10 minute averages

Table 11
Mean Skin Temperatures (°C)
Condition 5 (Cold, Wet, Exercise, Fatigue)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	33.9	34.0	27.7	31.4	33.0	33.4	32.6	33.3	37.6	33.4	33.5	33.3	31.0	32.9
5	32.7	32.4	32.5	29.7	31.6	31.3	30.6	31.9	32.2	31.2	32.0	32.6	29.5	31.5
15	30.7	30.9	30.6	27.5	28.8	28.4	26.3	29.7	30.4	29.0	29.7	30.2	27.6	29.4
25	30.5	32.2	31.3	28.7	27.8	28.0	28.5	30.4	30.4	29.0	30.3	29.7	28.3	29.6
35	30.5	31.3	30.8	26.7	27.3	27.4	27.6	29.7	30.2	28.4	29.8	29.7	28.6	29.1
45	29.7	31.4	31.1	27.1	26.4	27.2	27.1	29.8	29.9	27.9	29.5	28.8	27.3	28.7
55	29.8	32.3	31.0	26.6	26.7	27.7	26.7	30.5	29.8	27.7	30.0	29.9	27.7	28.9
65	29.6	31.5	29.2	24.2	27.2	27.4	26.3	29.3	29.3	27.7	29.3	29.3	27.4	28.3
75	29.7	30.9	28.9	23.7	26.8	27.3	26.0	28.3	29.3	27.8	28.7	28.9	27.6	28.0
85	29.4	30.9	28.1	26.6	26.3	27.0	26.0	28.2	29.5	27.8	28.8	29.2	28.1	28.1
95	29.2	30.9	28.4	26.5	26.4	26.5	26.0	28.3	29.5	27.6	28.8	28.9	28.1	28.1
105	28.9	30.4	28.3	26.5	26.6	26.6	25.9	28.1	29.4	27.7	28.9	28.7	28.2	28.0
115	29.0	30.6	26.5	25.3	26.1	26.4	25.8	27.8	29.1	27.7	28.7	28.7	28.0	27.7
120	28.5	30.0	26.2	26.5	26.2	26.6	25.7	27.4	28.9	27.6	28.7	28.3	27.8	27.6
125	28.1	29.9	26.6	25.5	25.5	26.9	25.7	27.3	29.0	27.7	28.5	28.4	27.6	27.4
135	26.1	29.8	27.3	25.2	26.0	26.7	25.5	27.5	28.9	27.4	28.3	28.2	27.8	27.4

Table 12
Mean Skin Temperatures (°C)
Condition 6 (Warm)

minutes	1	3	4	5	6	8	9	10	11	12	13	14	15	1-15
0	34.7	34.9	34.4	33.9	32.6	32.8	33.2	34.7	33.6	33.4	33.5	34.1	33.6	33.8
5	34.0	34.8	34.0	33.6	32.6	32.8	33.1	34.4	33.6	33.5	33.1	33.9	33.4	33.6
15	33.3	34.9	33.8	33.6	32.7	32.7	33.0	33.9	33.3	33.5	32.6	33.7	33.4	33.4
25	33.1	34.7	33.6	33.5	32.5	32.6	32.8	32.0	33.0	33.1	32.3	33.4	32.9	33.0
35	32.9	34.7	33.4	33.0	32.5	32.5	33.0	33.5	33.0	32.9	32.1	33.2	32.5	33.0
45	32.9	34.6	33.4	32.3	32.5	32.3	33.0	33.4	33.0	32.9	32.1	33.0	32.1	32.9
55	32.7	34.5	33.2	32.2	32.3	32.1	33.0	33.2	32.8	32.6	32.0	32.7	32.1	32.7
65	32.9	34.1	32.8	31.8	31.8	31.8	32.5	33.0	32.5	32.3	31.8	32.3	32.2	32.4
75	32.9	33.9	32.8	32.0	31.9	31.8	32.5	33.1	32.6	32.5	31.8	32.2	32.2	32.5
85	33.0	33.9	32.8	31.5	32.1	31.8	32.6	33.3	32.7	32.8	32.2	32.5	32.5	32.6
95	33.3	33.7	33.0	31.5	31.8	31.8	32.4	33.2	32.7	32.5	32.0	32.4	32.5	32.5
105	33.5	33.8	32.6	31.3	32.0	31.8	32.9	33.1	32.7	32.6	32.3	32.6	32.8	32.6
115	33.0	33.9	32.6	30.9	31.7	31.8	32.3	33.0	32.6	32.5	32.2	32.6	32.4	32.4
120	33.1	33.8	32.6	31.3	31.8	31.9	32.3	32.8	32.6	32.3	32.0	32.7	32.5	32.4
125	33.0	33.9	32.5	31.2	31.6	32.1	32.4	32.8	32.6	32.1	31.9	32.8	32.4	32.4

Column numbers are the subject identifiers
Temperatures are 10 minute averages

Appendix III

Table 1
Condition 1 (Cold)

Subject #	Temperature Perception 30	60	90	120	150	Comfort Perception 30	60	90	120	150
1	38	26	16	12	5	43	37	17	12	9
3	68	58	50	48	44	71	61	48	48	46
4	82	74	61	55		83	76	59	55	
5		31	31	22	9		34	29	29	11
6	82	81	51	48	29	83	79	50	47	15
8	43	34	27	27	11	46	33	27	29	21
9	75	41	3	2	2	85	35	18	8	-1
10	65	37	21	54	57	70	32	15	52	61
11	54	45	2	17	17	58	64	22	25	32
12	20	3	0	0	0	25	8	2	0	0
13	88	90	69	62	69	77	87	43	58	77
14	72	55	12	53	30	76	56	21	66	48
15	77	68	58	42	23	77	68	59	47	30
mean	63.7	49.5	30.8	34.0	24.7	66.2	51.5	31.5	36.6	29.1

Table 2
Condition 2 (Cold, Wet)

Subject #	Temperature Perception 30	60	90	120	150	Comfort Perception 30	60	90	120	150
1	28	15	2	0	1	31	18	2	0	0
3	70	44	31	28		61	44	31	30	
4	87	71	55	46	45	89	72	58	50	52
5	49	57	32	21	19	39	38	11	9	8
6	92	71	57	52	27	91	72	57	51	25
8	69	51	32	26	29	80	53	26	25	31
9	96	57	27	0	3	93	53	23	0	0
10	61	53	37	18	38	63	54	15	37	39
11	23	25	20	8	16	22	29	22	10	6
12	53	10	0	1	0	53	7	1	1	1
13	39	20	36	36	37	37	25	38	39	38
14	46	20	16	4	19	44	19	16	3	18
15	76	65	58	47	35	76	73	58	48	36
mean	60.7	43.0	31.0	22.1	22.4	59.9	42.8	27.5	23.3	21.2

Data is in mm between 0-100.

Table 3
Condition 3 (Cold, Wet, Fatigue)

Subject #	Temperature Perception 30	60	90	120	150	Comfort Perception 30	60	90	120	150
1	37	24	9	2	-1	40	27	13	2	1
3	56	36	16	6	9	64	31	21	8	31
4	88	71	55	44	27	88	73	56	50	24
5	25	10	18	32	5	38	21	20	30	9
6		32	20	14	16		36	25	18	16
8	48	32	21	22	13	38	21	14	25	15
9	82	42	2	1	6	87	45	3	3	2
10	50	32	9	12	54	53	24	7	15	53
11	61	61	37	42	39	64	61	49	46	46
12	69	41	4	0	0	59	35	3	0	0
13	60	67	42	22	22	60	65	34	31	22
14	75	29	25	10	4	76	30	20	9	4
15	84	65	47	27	14	84	59	44	25	16
mean	61.3	41.7	23.5	18.0	16.0	62.6	40.6	23.8	20.2	18.4

Table 4
Condition 4 (Cold, Wet, Exercise)

Subject #	Temperature Perception 30	60	90	120	150	Comfort Perception 30	60	90	120	150
1	62	45	21	7	3	72	50	28	11	3
3	19	39	2	-6	-6	19	59	0	-4	-5
4	88	66	55	35	36	82	62	54	45	40
5	62	47	34	24	13	64	43	25	11	15
6	73	73	55	13	36	68	72	49	19	32
8	51	42	31	23	27	57	44	27	23	25
9	97	95	60	7	4	99	93	59	10	-4
10	68	55	29	28	32	76	53	28	17	33
11	47	50	34	29	20	57	55	32	33	22
12	42	22	2	4	4	32	28	3	0	0
13	84	89	78	65	74	85	93	79	78	75
14	85	51	18	4	2	88	53	11	5	1
15	91	84	67	54	30	89	66	61	43	21
mean	66.8	58.3	37.4	22.1	21.2	68.3	59.3	35.1	22.4	19.5

Data is in mm between 0-100.

Table 5
Condition 5 (Cold, Wet, Exercise, Fatigue)

	Temperature Perception					Comfort Perception				
Subject #	30	60	90	120	150	30	60	90	120	150
1		33	13	11			42	19	11	
3	64	34	17	2		73	41	10	2	
4	88	68	46	28	25	82	72	44	43	43
5	58	37	18	3	5	58	40	18	3	12
6	78	76	49	9	12	77	73	50	10	11
8	38	34	32	30	23	38	33	35	29	23
9	96	90	66	14	13	97	87	50	19	9
10	74	58	20	32	45	78	65	50	38	49
11	46	37	5	2	3	63	53	1	3	5
12	36	25	4	0	0	58	27	2	-3	0
13		33	25	18	17		36	19	17	14
14	72	27	10	5	2	68	31	8	6	3
15	75	64	36	13	6	76	53	31	16	1
mean	65.9	47.4	26.2	12.8	13.7	69.8	50.2	25.9	14.9	15.5

Table 6
Condition 6 (Warm)

	Temperature Perception					Comfort Perception				
Subject #	30	60	90	120	150	30	60	90	120	150
1	76	89	89	89		77	85	81	83	86
3	95	94	97	97		92	94	98	94	
4	94	96	97	97		93	95	95	93	
5	77	69	74	65		52	55	60	56	
6	97	93	95	94		96	91	98	94	
8	77	78	77	78		79	80	72	74	
9	100	99	92	97		93	98	96	98	
10	84	86	85	86		93	85	86	89	
11	73	72	84	83		81	83	84	84	
12	100	100	100	100		101	100	102	100	
13	97	97	98			97	64	70		
14	99	100	100	100		100	99	99	99	
15	92	92	94	90		95	96	92	92	
mean	89.3	89.6	90.9	89.7		88.4	86.5	87.2	88.0	86.0

Data is in mm between 0-100.

Appendix IV

Tables 1a-f
F.A.T.S. Shooting Performance, 100 yard Range Targets

Table 1a
Condition 1 (Cold)

Subject #	Shot Grouping	Total Time	Total Hits	Total Shots
1	64.2	151	40	40
3	85.4	157	39	40
4	74.9	113	40	40
5	71.4	160	36	40
6	100.3	196	40	40
8	110.9	104	38	40
9	132.4	124	37	40
10	58.9	113	36	40
11	67.5	162	39	39
12	66.4	138	40	40
13	74.2	182	38	38
14	80.9	171	37	40
15	69.3	144	40	40
means	81.3	159.1	39.3	39.9

Shot grouping = Total distance between shots for four targets.

Table 1b.
Condition 2 (Cold, Wet)

Subject #	Shot Grouping	Total Time	Total Hits	Total Shots
1	48.8	180	38	40
3	79.2	121	38	40
4	75.4	127	40	40
5	44.3	153	38	40
6	111.7	139	39	40
8	120.1	83	37	40
9	115.6	126	40	40
10	64.6	116	30	40
11	92.6	152	38	40
12	60.8	162	38	40
13	64.1	115	40	40
14	57.9	142	35	40
15	82.5	114	39	40
means	78.9	133.1	37.7	40.0

Shot grouping = Total distance between shots for four targets.

Table 1 (cont.)
F.A.T.S. Shooting Performance, 100 yard Range Targets

Table 1c.
Condition 3 (Cold, Wet, Fatigue)

Subject #	Shot Grouping	Total Time	Total Hits	Total Shots
1	69.4	168	39	40
3	78.2	154	40	40
4	73.8	104	40	40
5	70.7	186	34	35
6	132.3	180	40	40
8	91.5	93	37	40
9	83.3	147	38	40
10	71.5	152	37	40
11	72.9	172	37	38
12	65.1	81	40	40
13	75.4	138	40	40
14	73.4	127	35	40
15	76.3	120	40	40
means	**79.5**	**140.2**	**38.2**	**39.5**

Shot grouping = Total distance between shots for four targets.

Table 1d.
Condition 4 (Cold, Wet, Exercise)

Subject #	Shot Grouping	Total Time	Total Hits	Total Shots
1	36.7	143	40	40
3	73.7	146	39	40
4	61.8	113	39	40
5	64.4	143	39	40
6	71.0	163	40	40
8	91.5	88	40	40
9	104.7	110	40	40
10	72.5	99	40	40
11	71.3	148	35	40
12	65.3	84	40	40
13	59.3	179	39	40
14	68.2	152	34	40
15	71.6	130	40	40
means	**70.2**	**130.6**	**38.8**	**40.0**

Shot grouping = Total distance between shots for four targets.

Table 1 (cont.)
F.A.T.S. Shooting Performance, 100 yard Range Targets

Table 1e.
Condition 5 (Cold, Wet, Exercise, Fatigue)

Subject #	Shot Grouping	Total Time	Total Hits	Total Shots
1	52.2	138	40	40
3	72.7	145	40	40
4	69.9	112	40	40
5	78.3	142	38	40
6	89.1	170	40	40
8	77.7	81	40	40
9	92.9	157	40	40
10	70.1	113	39	40
11	81.3	142	35	40
12	62.7	135	40	40
13	69.8	140	39	40
14	47.3	144	39	40
15	51.3	199	38	40
means	70.4	139.8	39.1	40.0

Shot grouping = Total distance between shots for four targets.

Table 1f.
Condition 6 (Warm)

Subject #	Shot Grouping	Total Time	Total Hits	Total Shots
1	56.2	226	39	39
3	79.0	145	40	40
4	55.1	117	36	40
5	72.7	169	38	40
6	94.3	145	40	40
8	89.6	141	40	40
9	80.9	179	40	40
10	58.5	133	39	40
11	69.7	145	38	40
12	62.0	103	40	40
13	58.4	171	38	40
14	49.3	199	36	39
15	71.6	133	40	40
means	69.0	154.3	38.8	39.8

Shot grouping = Total distance between shots for four targets

Table 2a-f
"Moving Target" Shooting Performance

Table 2a. Condition 1 (Cold)

Subject #	Hits	Shots	% of Targets hit	% of Shots that hit
1	6	7	75.0%	85.7%
3	4	8	50.0%	50.0%
4	5	8	62.5%	62.5%
5	2	8	25.0%	25.0%
6	6	8	75.0%	75.0%
8	5	8	62.5%	62.5%
9	3	8	37.5%	37.5%
10	4	8	50.0%	50.0%
11	3	8	37.5%	37.5%
12	5	8	62.5%	62.5%
13	3	8	37.5%	37.5%
14	3	8	37.5%	37.5%
15	7	8	87.5%	87.5%
mean	4.3	7.9	53.8%	54.7%

Table 2b. Condition 2 (Cold, Wet)

Subject #	Hits	Shots	% of Targets hit	% of Shots that hit
1	4	5	50.0%	80.0%
3	5	8	62.5%	62.5%
4	5	8	62.5%	62.5%
5	2	8	25.0%	25.0%
6	3	8	37.5%	37.5%
8	5	8	62.5%	62.5%
9	5	8	62.5%	62.5%
10	5	8	62.5%	62.5%
11	5	8	62.5%	62.5%
12	5	8	62.5%	62.5%
13	2	8	25.0%	25.0%
14	2	8	25.0%	25.0%
15	5	7	62.5%	71.4%
mean	4.1	7.7	51.0%	54.0%

Table 2c. Condition 3 (Cold,Wet, Fatigue)

Subject #	Hits	Shots	% of Targets hit	% of Shots that hit
1	6	7	75.0%	85.7%
3	3	7	37.5%	42.9%
4	6	8	75.0%	75.0%
5	3	6	37.5%	50.0%
6	7	8	87.5%	87.5%
8	4	7	50.0%	57.1%
9	5	8	62.5%	62.5%
10	4	7	50.0%	57.1%
11	4	7	50.0%	57.1%
12	4	8	50.0%	50.0%
13	3	8	37.5%	37.5%
14	1	8	12.5%	12.5%
15	7	8	87.5%	87.5%
mean	4.4	7.5	54.8%	58.7%

Table 2d.Condition 4 (Cold, Wet, Exercise)

Subject #	Hits	Shots	% of Targets hit	% of Shots that hit
1	3	6	37.5%	50.0%
3	5	8	62.5%	62.5%
4	6	8	75.0%	75.0%
5	2	6	25.0%	33.3%
6	5	8	62.5%	62.5%
8	6	8	75.0%	75.0%
9	5	8	62.5%	62.5%
10	3	8	37.5%	37.5%
11	4	6	50.0%	66.7%
12	5	8	62.5%	62.5%
13	5	8	62.5%	62.5%
14	3	6	37.5%	50.0%
15	4	7	50.0%	57.1%
mean	4.3	7.3	53.8%	58.2%

Table 2e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Subject #	Hits	Shots	% of Targets hit	% of Shots that hit
1	4	7	50.0%	57.1%
3	4	7	50.0%	57.1%
4	5	8	62.5%	62.5%
5	3	8	37.5%	37.5%
6	2	8	25.0%	25.0%
8	3	8	37.5%	37.5%
9	6	8	75.0%	75.0%
10	4	8	50.0%	50.0%
11	4	7	50.0%	57.1%
12	5	7	62.5%	71.4%
13	1	8	12.5%	12.5%
14	2	8	25.0%	25.0%
15	5	8	62.5%	62.5%
mean	3.7	7.7	46.2%	48.5%

Table 2f. Condition 6 (Warm)

Subject #	Hits	Shots	% of Targets hit	% of Shots that hit
1	4	7	50.0%	57.1%
3	3	8	37.5%	37.5%
4	6	8	75.0%	75.0%
5	4	8	50.0%	50.0%
6	6	8	75.0%	75.0%
8	6	8	75.0%	75.0%
9	5	8	62.5%	62.5%
10	4	8	50.0%	50.0%
11	6	8	75.0%	75.0%
12	5	8	62.5%	62.5%
13	4	8	50.0%	50.0%
14	3	8	37.5%	37.5%
15	5	8	62.5%	62.5%
mean	4.7	7.9	58.7%	59.2%

Tables 3a-f
"Quick Kill" Shooting Performance

Table 3a. Condition 1 (Cold)

Subject	# Hits	Shots	% of Targets hit	% of Shots that hit
1	26	31	48.1%	83.9%
3	9	50	16.7%	18.0%
4	26	49	48.1%	53.1%
5	20	47	37.0%	42.6%
6	25	33	46.3%	75.8%
8	13	49	24.1%	26.5%
9	28	50	51.9%	56.0%
10	35	41	64.8%	85.4%
11	19	52	35.2%	36.5%
12	17	48	31.5%	35.4%
13	27	38	50.0%	71.1%
14	0	46	0.0%	0.0%
15	22	53	40.7%	41.5%
mean	20.5	45.2	38.0%	48.1%

Table 3b. Condition 2 (Cold, Wet)

Subject	# Hits	Shots	% of Targets hit	% of Shots that hit
1	29	32	53.7%	90.6%
3	15	51	27.8%	29.4%
4	32	52	59.3%	61.5%
5	20	47	37.0%	42.6%
6	24	45	44.4%	53.3%
8	29	52	53.7%	55.8%
9	18	43	33.3%	41.9%
10	29	33	53.7%	87.9%
11	21	52	38.9%	40.4%
12	17	46	31.5%	37.0%
13	27	34	50.0%	79.4%
14	5	52	9.3%	9.6%
15	20	52	37.0%	38.5%
mean	22.0	45.5	40.7%	51.4%

Table 3c. Condition 3 (Cold, Wet, Fatigue)

Subject	# Hits	Shots	% of Targets hit	% of Shots that hit
1	27	31	50.0%	87.1%
3	12	45	22.2%	26.7%
4	26	52	48.1%	50.0%
5	19	45	35.2%	42.2%
6	27	38	50.0%	71.1%
8	16	49	29.6%	32.7%
9	24	38	44.4%	63.2%
10	23	37	42.6%	62.2%
11	21	54	38.9%	38.9%
12	30	40	55.6%	75.0%
13	25	38	46.3%	65.8%
14	6	46	11.1%	13.0%
15	18	54	33.3%	33.3%
mean	21.1	43.6	39.0%	50.9%

Table 3d. Condition 4 (Cold, Wet, Exercise)

Subject	# Hits	Shots	% of Targets hit	% of Shots that hit
1	29	34	53.7%	85.3%
3	13	40	24.1%	32.5%
4	24	50	44.4%	48.0%
5	22	47	40.7%	46.8%
6	29	43	53.7%	67.4%
8	8	52	14.8%	15.4%
9	24	50	44.4%	48.0%
10	32	33	59.3%	97.0%
11	25	49	46.3%	51.0%
12	12	49	22.2%	24.5%
13	24	31	44.4%	77.4%
14	3	49	5.6%	6.1%
15	25	53	46.3%	47.2%
mean	20.8	44.6	38.5%	49.7%

Table 3e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Subject	# Hits	Shots	% of Targets hit	% of Shots that hit
1	29	33	53.7%	87.9%
3	16	42	29.6%	38.1%
4	22	54	40.7%	40.7%
5	22	50	40.7%	44.0%
6	22	46	40.7%	47.8%
8	19	53	35.2%	35.8%
9	28	45	51.9%	62.2%
10	27	31	50.0%	87.1%
11	27	54	50.0%	50.0%
12	25	38	46.3%	65.8%
13	29	39	53.7%	74.4%
14	3	40	5.6%	7.5%
15	21	48	38.9%	43.8%
mean	22.3	44.1	41.3%	52.7%

Table 3f. Condition 6 (Warm)

Subject	# Hits	Shots	% of Targets hit	% of Shots that hit
1	27	32	50.0%	84.4%
3	18	43	33.3%	41.9%
4	22	50	40.7%	44.0%
5	28	34	51.9%	82.4%
6	22	35	40.7%	62.9%
8	26	52	48.1%	50.0%
9	32	44	59.3%	72.7%
10	28	30	51.9%	93.3%
11	32	53	59.3%	60.4%
12	22	34	40.7%	64.7%
13	24	35	44.4%	68.6%
14	7	47	13.0%	14.9%
15	28	53	51.9%	52.8%
mean	24.3	41.7	45.0%	61.0%

Tables 4a-f
Judgemental Shooting Tables

Table 4a. Condition 1 (Cold)

Subject #	Judgement	Hit %	Mean Rxn
1	80%	80.0%	0.550
3	100%	57.1%	0.256
4	100%	85.7%	0.478
5	100%	60.0%	0.644
6	80%	100.0%	0.944
8	100%	100.0%	0.867
9	80%	80.0%	0.467
10	100%	100.0%	0.744
11	100%	50.0%	0.633
12	80%	80.0%	0.722
13	100%	33.3%	1.300
14	80%	40.0%	0.700
15	100%	85.7%	0.689
means	92.3%	73.2%	0.692

Table 4d. Condition 4 (Cold, Wet, Exercise)

Subject #	Judgement %	Hit %	Mean Rxn
1	80.0%	100.0%	1.017
3	80.0%	80.0%	0.500
4	100.0%	50.0%	1.088
5	80.0%	100.0%	0.833
6	100.0%	57.1%	-0.356
8	100.0%	80.0%	0.678
9	80.0%	85.7%	0.567
10	100.0%	50.0%	1.022
11	80.0%	100.0%	0.584
12	80.0%	66.7%	0.467
13	80.0%	100.0%	1.033
14	100.0%	57.1%	0.389
15	80.0%	100.0%	0.511
means	87.7%	79.0%	0.641

Table 4b. Condition 2 (Cold, Wet)

Subject #	Judgement %	Hit %	Mean Rxn
1	60.0%	100.0%	0.999
3	60.0%	100.0%	0.767
4	100.0%	100.0%	0.711
5	100.0%	71.4%	0.767
6	100.0%	33.3%	1.411
8	100.0%	80.0%	0.322
9	80.0%	83.3%	0.744
10	60.0%	100.0%	0.700
11	100.0%	55.6%	0.611
12	80.0%	83.3%	0.756
13	100.0%	83.3%	0.567
14	80.0%	50.0%	0.550
15	100.0%	33.3%	1.033
means	86.2%	74.9%	0.764

Table 4e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Subject #	Judgement %	Hit %	Mean Rxn
1	80.0%	50.0%	1.178
3	100.0%	28.6%	1.155
4	80.0%	100.0%	0.978
5	80.0%	66.7%	0.800
6	80.0%	85.7%	0.767
8	80.0%	100.0%	0.667
9	100.0%	66.7%	1.078
10	60.0%	100.0%	1.134
11	100.0%	71.4%	0.511
12	80.0%	37.5%	0.966
13	100.0%	83.3%	0.878
14	100.0%	42.9%	0.633
15	80.0%	50.0%	0.778
means	86.2%	67.9%	0.886

Table 4c. Condition 3 (Cold, Wet, Fatigue)

Subject #	Judgement %	Hit %	Mean Rxn
1	80.0%	75.0%	0.533
3	80.0%	42.9%	0.556
4	100.0%	88.9%	0.650
5	100.0%	22.2%	0.866
6	80.0%	100.0%	1.000
8	100.0%	83.3%	0.867
9	100.0%	100.0%	0.833
10	100.0%	100.0%	0.683
11	100.0%	40.0%	1.200
12	100.0%	100.0%	0.967
13	80.0%	83.3%	0.689
14	80.0%	44.4%	0.700
15	100.0%	85.7%	0.822
means	92.3%	74.3%	0.797

Table 4f. Condition 6 (Warm)

Subject #	Judgement %	Hit %	Mean Rxn
1	100.0%	83.3%	0.878
3	100.0%	100.0%	0.900
4	100.0%	66.7%	0.789
5	100.0%	66.7%	0.800
6	100.0%	100.0%	0.722
8	80.0%	75.0%	0.583
9	100.0%	100.0%	0.944
10	100.0%	100.0%	0.456
11	100.0%	80.0%	0.711
12	100.0%	100.0%	0.333
13	80.0%	77.8%	0.589
14	100.0%	16.7%	0.922
15	100.0%	100.0%	0.656
means	96.9%	82.0%	0.737

Tables 1a-b
Grip Strength Tests

Table 1a. Condition 1 (Cold)

Subject #	Pre test 1	Pre Test 2	Pre Mean	Test 1	Test 2	Test Mean	Pre Test minus Test	% change
1	51.0	50.0	50.5	52.5	49.0	50.8	-0.25	-0.5
3	46.0	40.0	43.0	40.0	41.0	40.5	2.5	5.81
4	42.0	43.0	42.5	43.0	50.0	46.5	-4.0	-9.41
5	53.0	52.5	52.8	50.0	48.0	49.0	3.75	7.11
6	54.0	48.0	51.0	50.0	48.0	49.0	2.0	3.92
8	70.0	60.0	65.0	62.0	59.0	60.5	4.5	6.92
9	48.0	45.0	46.5	35.0	38.5	36.8	9.75	20.97
10	46.0	48.0	47.0	37.5	39.5	38.5	8.5	18.0
11	47.0	47.0	47.0	42.0	42.0	42.0	5.0	10.64
12	56.0	54.0	55.0	49.0	45.0	47.0	8.0	14.5
13	40.0	41.0	40.5	42.5	42.5	42.5	-2.0	-4.94
14	63.0	58.0	60.5	49.0	49.0	49.0	11.5	19.0
15	54.5	51.0	52.8	54.0	49.0	51.5	1.25	2.37
mean			50.31			46.42	3.88	7.27

Table 1b. Condition 2 (Cold, Wet)

Subject #	Pre test 1	Pre Test 2	Pre Mean	Test 1	Test 2	Test Mean	Pre Test minus Test	% change
1	57.0	55.0	56.0	49.0	48.0	48.5	7.5	13.39
3	44.0	40.0	42.0	39.0	38.0	38.5	3.5	8.33
4	44.0	39.0	41.5	45.0	43.0	44.0	-2.5	-6.0
5	53.0	51.0	52.0	49.5	55.5	52.5	-0.5	-0.96
6	53	54	53.5	51	47.5	49.3	4.25	7.94
8	65.5	68.5	67.0	37.5	43.0	40.3	26.75	39.93
9	50.0	45.5	47.8	33.0	29.0	31.0	16.75	35.0
10	45	43.5	44.3	32.0	36.0	34.0	10.25	23.16
11	37.5	48.0	42.8	42.0	43.0	42.5	0.25	0.5
12	55.0	58.0	56.5	54.0	52.0	53.0	3.5	6.19
13	40.0	45.0	42.5	42.0	45.0	43.5	-1.0	-2.35
14	48.5	45.0	46.8	43.5	45.5	44.5	2.25	4.81
15	59.5	50.0	54.8	58.0	48.0	53.0	1.75	3.20
mean			49.79			44.19	5.60	10.25

Tables 1c-d
Grip Strength Tests

Table 1c. Condition 3. (Cold, Wet, Fatigue)

Subject #	Pre test 1	Pre Test 2	Pre Mean	Test 1	Test 2	Test Mean	Pre Test minus Test	% change
1	56.0	54.0	55.0	45.0	50.0	47.5	7.5	13.64
3	45.0	40.0	42.5	36.0	33.0	34.5	8.0	18.82
4	40.0	43.0	41.5	37.0	42.0	39.5	2.0	4.82
5	57.0	50.0	53.5	40.0	35.0	37.5	16.0	29.91
6	48.0	48.0	48.0	48.0	48.0	48.0	0.0	0.0
8	63.0	60.0	61.5	60.0	60.0	60.0	1.5	2.44
9	50.0	45.0	47.5	32.0	33.5	32.8	14.75	31.0
10	46.0	40.0	43.0	37.0	32.0	34.5	8.5	19.77
11	49.0	48.0	48.5	47.0	47.0	47.0	1.5	3.0
12	62.0	63.0	62.5	57.0	63.0	60.0	2.5	4.0
13	38.0	44.0	41.0	38.0	45.5	41.8	-0.75	-1.83
14	65.0	62.0	63.5	55.0	55.0	55.0	8.5	13.39
15	56.0	53.0	54.5	52.0	51.0	51.5	3.0	5.5
mean			50.96			45.35	5.62	11.12

Table 1d. Conditon 4 (Cold, Wet, Exercise)

Subject #	Pre test 1	Pre Test 2	Pre Mean	Test 1	Test 2	Test Mean	Pre Test minus Test	% change
1	60.0	55.0	57.5	45.5	48.0	46.8	10.75	18.70
3	38.0	38.5	38.3	25.5	21.5	23.5	14.75	38.5
4	41.0	42.0	41.5	41.0	36.0	38.5	3.0	7.23
5	53.0	50.5	51.8	56.0	58.5	57.3	-5.5	-10.63
6	47.5	47.0	47.3	42.0	43.0	42.5	4.75	10.0
8	69.0	69.0	69.0	61.0	61.0	61.0	8.0	11.5
9	52.5	51.0	51.8	41.5	41.5	41.5	10.25	19.81
10	49.0	48.0	48.5	42.0	47.5	44.8	3.75	7.73
11	46.0	46.0	46.0	38.0	39.5	38.8	7.25	15.76
12	56.0	55.0	55.5	53.0	51.0	52.0	3.5	6.31
13	41.0	42.0	41.5	40.0	38.0	39.0	2.5	6.0
14	67.0	63.0	65.0	51.0	54.5	52.8	12.25	18.85
15	57.0	56.0	56.5	59.0	55.0	57.0	-0.5	-0.88
mean			51.5			45.79	5.75	11.47

Tables 1e-f
Grip Strength Tests

Table 1e. Conditon 5 (Cold, Wet, Exercise, Fatigue)

Subject #	Pre test 1	Pre Test 2	Pre Mean	Test 1	Test 2	Test Mean	Pre Test minus Test	% change
1	55.0	56.0	55.5	53.5	56.5	55.0	0.5	0.90
3	45.0	44.0	44.5	31.0	41.0	36.0	8.5	19.10
4	34.0	37.0	35.5	41.0	41.0	41.0	-5.5	-15.49
5	44.0	44.0	44.0	46.0	47.0	46.5	-2.5	-5.68
6	55.5	55.0	55.3	49.0	51.0	50.0	5.25	9.5
8	60.0	68.5	64.3	58.0	60.0	59.0	5.25	8.17
9	47.0	49.0	48.0	48.5	47.5	48.0	0.0	0.0
10	46.0	46.5	46.3	36.0	36.0	36.0	10.25	22.16
11	48.0	46.0	47.0	45.0	43.0	44.0	3.0	6.38
12	61.0	64.0	62.5	58.0	54.0	56.0	6.5	10.40
13	48.0	45.0	46.5	43.0	46.5	44.8	1.75	3.76
14	65.0	61.0	63.0	55.0	54.0	54.5	8.5	13.49
15	57.0	52.0	54.5	56.0	57.0	56.5	-2.0	-3.67
mean			51.29			48.25	3.0	5.31

Table 1f. Condition 6 (Warm)

Subject #	Pre test 1	Pre Test 2	Pre Mean	Test 1	Test 2	Test Mean	Pre Test minus Test	% change
1	57	55	56.0	52	57	54.5	1.5	2.68
3	46	40	43.0	40	41	40.5	2.5	5.81
4	39	36	37.5	46	43.5	44.8	-7.25	-19.33
5	53.5	48	50.8	52	50	51.0	-0.25	-0.49
6	49.5	55.5	52.5	51	47	49.0	3.5	6.67
8	70	68	69.0	73.5	74	73.8	-4.75	-6.88
9	50	46	48.0	41	42	41.5	6.5	13.5
10	51	49	50.0	45	48	46.5	3.5	7.0
11	51	46	48.5	49	49	49.0	-0.5	-1.0
12	61	63	62.0	61	65	63.0	-1.0	-1.61
13	39	41	40.0	45	48	46.5	-6.5	-16.25
14	56	56	56.0	47	45	46.0	10.0	17.86
15	54	54	54.0	53.5	40	46.8	7.25	13.43
mean			51.33			50.21	1.12	1.64

Tables 2a-c Dexterity Tests

O'Connor Tweezer Test | **Grooved Pegboard**

Table 2a. Condition 1 (Cold)

Subject #	Number of Pins placed	Number of Pins dropped	Time (sec) 25 Pegs	Number of Pegs dropped
1	41	2	89	0
3	51	1	52	0
4	42	0	80	0
5	30	2	100	1
6	48	0	71	0
8	57	1	48	0
9	34	4	117	0
10	33	2	84	0
11	44	5	62	0
12	56	0	72	0
13	49	0	93	0
14	48	0	64	0
15	30	18	66	1
mean	43.31	2.69	76.77	0.15

Table 2b. Condition 2 (Cold, Wet)

Subject #	Number of Pins placed	Number of Pins dropped	Time (sec) 25 Pegs	Number of Pegs dropped
1	44	1	80	0
3	41	1	66	0
4	42	0	91	1
5	35	1	83	0
6	53	0	59	0
8	47	2	68	0
9	32	4	107	3
10	14	7	146	3
11	33	3	65	0
12	60	1	69	0
13	43	3	94	2
14	48	1	72	0
15	47	2	58	0
mean	41.46	2.00	81.38	0.69

Table 2c. Condition 3 (Cold, Wet, Fatigue)

Subject #	Number of Pins placed	Number of Pins dropped	Time (sec) 25 Pegs	Number of Pegs dropped
1	48	0	74	0
3	41	0	67	0
4	40	0	84	0
5	25	1	84	2
6	34	0	81	0
8	54	1		
9	31	7	106	0
10	29	4	100	0
11	48	2	64	0
12	56	0	127	1
13	52	5	96	1
14	48	1	62	0
15	49	4	57	0
mean	42.69	1.92	83.50	0.33

Tables 2d-f Dexterity Tests

O'Connor Tweezer Test | **Grooved Pegboard**

Table 2d. Condition 4 (Cold, Wet, Exercise)

Subject #	Number of Pins placed	Number of Pins dropped	Time (sec) 25 Pegs	Number of Pegs dropped
1	55	0	79	0
3	31	4	95	0
4	36	0	91	0
5	29	2	78	0
6	46	0	116	0
8	51	0	55	0
9	37	5	125	1
10	38	1	92	1
11	28	1	66	0
12	45	0	83	1
13	52	3	111	0
14	45	3	69	1
15	55	1	56	1
mean	42.00	1.54	85.85	0.38

Table 2e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Subject #	Number of Pins placed	Number of Pins dropped	Time (sec) 25 Pegs	Number of Pegs dropped
1	43	0	76	0
3	33	0	75	0
4	27	1	125	1
5	25	2	95	1
6	48	0	85	0
8	59	1	58	0
0	45	1	96	0
10	16	10	146	3
11	64	0	69	0
12	54	1	68	0
13	46	1	98	3
14	49	2	59	0
15	43	4	62	0
mean	42.46	1.77	85.54	0.62

Table 2f. Condition 6 (Warm)

Subject #	Number of Pins placed	Number of Pins dropped	Time (sec) 25 Pegs	Number of Pegs dropped
1	45	0	67	0
3	51	1	52	0
4	45	1	60	0
5	36	2	64	1
6	60	0	48	0
8	48	2	49	1
9	46	4	71	0
10	51	2	55	0
11	57	0	43	0
12	67	0	59	0
13	40	3	69	0
14	53	5	50	0
15	64	1	45	0
mean	51.00	1.62	56.31	0.15

Tables 1a-f
CCAB - Following Directions

Table 1a. Condition 1 (Cold)

Sub #	Score	Total Time	Mean Time
1	1265	95.2	6.13
3	1806	63	4.96
4	1275	92.8	5.97
5	1045	120	6.36
6	1219	106.8	7.52
8	1495	86.3	5.44
9	1167	100.4	7.12
10	1834	59.7	4.18
11	1179	112	6.13
12	1553	80.6	5.33
13	1281	106.9	4.49
14	1741	66.9	4.94
15	990	120	8.11
Means	1373.08	93.12	5.90

Table 1b. Condition 2 (Cold, Wet)

Sub #	Score	Total Time	Mean Time
1	1191	102.7	7.52
3	1810	63.9	4.78
4	1766	61.9	7.54
5	1026	120	7.59
6	1236	106.5	7.29
8	1015	120	7.21
9	948	120	7.98
10	1605	77.4	5.41
11	1235	101.5	7.33
12	1707	71.6	5.51
13	1455	94.6	6.62
14	1235	108.1	5.19
15	1476	79	7.07
Means	1361.92	94.40	6.70

Table 1c. Condition 3 (Cold, Wet, Fatigue)

Sub #	Score	Total Time	Mean Time
1	1348	91.3	4.14
3	*	*	*
4	1255	96.3	5.94
5	981	120	7.8
6	1058	115.6	[illegible].2
8	14[illegible]	90.5	6.25
9	1211	101.7	7.44
10	1362	95.8	5.62
11	1557	61.8	5.94
12	1433	86.8	6.63
13	1463	94.7	6.24
14	1520	72.1	4.77
15	1456	81.9	5.85
Means	1338.25	94.04	6.24

Table 1d. Condition 4 (Cold, Wet, Exercies)

Sub #	Score	Total Time	Mean Time
1	1457	83	3.44
3			
4	1560	71.6	4.98
5	1498	82.5	5.85
6	1328	95.2	7.54
8	1007	120	5.57
9	984	120	4.4
10	1595	68.9	4.18
11	1221	99.9	5.81
12	1244	100.1	6.95
13	1582	85.8	4.97
14	1606	67.6	5.19
15	1691	70.5	5.69
Means	1397.58	88.76	5.38

Table 1e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Sub #	Score	Total Time	Mean Time
1	1493	84.5	4.81
3	1683	76.2	6.17
4	1523	77.9	5.83
5	981	120	5.56
6	1116	115.4	8.21
8	1791	65.2	1.17
9	1256	96.4	6.17
10	1801	62.9	4.43
11	1464	94.9	6.82
12	1364	90.2	5.95
13	1476	93.4	5.67
14	1922	52.4	3.9
15			
Means	1489.17	85.78	5.39

Table 1f. Condition 6 (Warm)

Sub #	Score	Total Time	Mean Time
1	1493	84.5	4.81
3	1683	76.2	6.17
4	1523	77.9	5.83
5	981	120	5.56
6	1116	115.4	8.21
8	1791	65.2	1.17
9	1256	96.4	6.17
10	1801	62.9	4.43
11	1464	94.9	6.82
12	1364	90.2	5.95
13	1476	93.4	5.67
14	1922	52.4	3.9
15			
Means	1489.17	85.78	5.39

Tables 2a-c
CCAB - Missing Items

Table 2a. Condition 1 (Cold)

Sub #	Score	Time	Accuracy	Letters Score	Letters Time	Letters Accuracy	Numbers Score	Numbers Time	Numbers Accuracy
1	1153	13.8	0.81	1270	11.3	0.81	1036	16.4	0.81
3	1321	4.1	0.72	1436	4.3	0.81	1205	4	0.63
4	1579	4.3	1.00	1802	4.1	1.00	1556	4.5	1.00
5	938	18.5	0.59	1141	13.3	0.81	736	23.7	0.38
6	1217	5.8	0.72	1536	5.7	1.00	897	5	0.44
8	1418	8.6	0.91	1510	7.6	1.00	1326	9.6	0.81
9	1294	11.3	0.91	1344	12.9	1.00	1244	9.6	0.81
10	1335	4.3	0.81	1611	3.7	1.00	1059	4.9	0.63
11	1275	12.7	0.91	1509	8	1.00	1042	17.4	0.81
12	1378	12.4	1.00	1510	8.2	1.00	1246	16.6	1.00
13	1550	6.5	1.00	1548	6.3	1.00	1553	6.6	1.00
14	1314	4.0	0.81	1601	3.9	1.00	1028	4.1	0.63
15	1479	7.9	1.00	1545	6	1.00	1413	9.5	1.00
Means	1327.00	8.8	0.86	1474.08	7.41	0.96	1180.08	10.17	0.76

Table 2b. Condition 2 (Cold, Wet)

Sub #	Score	Time	Accuracy	Letters Score	Letters Time	Letters Accuracy	Numbers Score	Numbers Time	Numbers Accuracy
1	1308	13.5	0.88	1483	8.9	1.00	1133	18.1	0.75
3	1485	4.5	0.91	1593	4.5	1.00	1379	4.5	0.81
4	1442	4.9	0.91	1376	3	0.81	15,8	6.7	1.00
5	1118	11.5	0.72	1251	10.4	0.81	984	12.5	0.63
6	1243	5.9	0.72	1529	7	1.00	957	4.9	0.44
8	1060	16.3	0.69	1457	10.2	1.00	662	22.5	0.38
9	1231	9.8	0.81	1217	9.6	0.81	1245	10	0.81
10	1173	13.2	0.81	1342	7.9	0.81	1004	18.5	0.81
11	1313	10.8	0.91	1442	10	1.00	1184	11.6	0.81
12	1193	15.6	0.78	1450	9.8	1.00	935	21.3	0.56
13	1367	9.3	0.91	1270	8.2	0.81	1463	10.4	1.00
14	1158	9.1	0.72	1391	6.3	0.81	926	12	0.63
15	1344	5.8	0.81	1562	5.3	1.00	1126	6.3	0.63
Means	1264.23	10.0	0.81	1412.54	7.78	0.91	1000.98	12.25	0.71

Table 2c. Condition 3 (Cold, Wet, Fatigue)

Sub #	Score	Time	Accuracy	Letters Score	Letters Time	Letters Accuracy	Numbers Score	Numbers Time	Numbers Accuracy
1	1428	6.3	0.91	1298	5.3	0.81	1558	7.3	1.00
3									
4	1390	7.8	0.91	1553	6	1.00	1226	9.7	0.83
5	1209	15.9	0.88	1158	14.9	0.75	1260	16.8	1.00
6	1052	11.1	0.63	1466	9.7	1.00	638	12.4	0.25
8	1312	10.1	0.81	1479	9	1.00	1145	11.3	0.63
9	1219	9.8	0.81	1211	9.1	0.81	1226	10.5	0.81
10	1089	9.8	0.63	1556	5.7	1.00	621	13.9	0.25
11	1253	11.1	0.81	1472	9.9	1.00	1035	12.2	0.63
12	1056	14.3	0.72	1401	10.5	1.00	711	18	0.44
13	1405	8.0	0.91	1298	7.6	0.81	1512	8.4	1.00
14	1189	2.3	0.63	1209	1.2	0.63	1169	3.4	0.63
15	1322	9.0	0.81	1538	6.5	1.00	1107	11.6	0.63
Means	1243.67	9.6	0.79	1386.58	7.95	0.90	1100.67	11.29	0.67

Tables 2d-f
CCAB - Missing Items

Table 2d. Condition 4 (Cold, Wet, Exercise)

Sub #	Score	Time	Accuracy	Letters Score	Letters Time	Letters Accuracy	Numbers Score	Numbers Time	Numbers Accuracy
1	1538	7.6	1.00	1497	8.5	1.00	1579	6.7	1.00
3									
4	1556	5.5	1.00	1599	4.3	1.00	1514	6.7	1.00
5	962	13.0	0.63	980	10.6	0.63	943	15.4	0.63
6	1412	8.4	0.92	1448	10.3	1.00	1377	6.5	0.81
8	1324	11.2	0.91	1543	6.7	1.00	1105	15.7	0.81
9	1235	9.9	0.81	1252	8.7	0.81	1217	11.2	0.81
10	1116	7.4	0.63	1550	6.3	1.00	681	8.5	0.25
11	1322	10.5	0.91	1472	9.4	1.00	1173	11.6	0.81
12	1164	13.2	0.81	1499	8.4	1.00	829	18	0.63
13	1397	8.1	0.91	1294	6.9	0.81	1499	9.2	1.00
14	1306	5.4	0.81	1127	4.2	0.63	1484	6.7	1.00
15	1518	6.6	1.00	1541	6.1	1.00	1495	7.2	1.00
Means	1320.83	8.9	0.86	1400.17	7.53	0.91	1241.33	10.28	0.81

Table 2e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Sub #	Score	Time	Accuracy	Letters Score	Letters Time	Letters Accuracy	Numbers Score	Numbers Time	Numbers Accuracy
1	1311	13.1	0.91	1276	11.2	0.81	1347	14.9	1.00
3	1473	5.1	0.91	1587	4.8	1.00	1358	5.5	0.81
4	1326	12.7	0.91	1429	10.5	1.00	1224	14.9	0.81
5	1257	10.3	0.81	1211	10.1	0.81	13.04	10.5	0.81
6	1116	6.6	0.63	1525	7.6	1.00	708	5.7	0.25
8	1431	7.6	0.91	1526	7.2	1.00	1335	7.9	0.81
9	1142	8.8	0.72	1001	9.2	0.63	1283	8.3	0.81
10	1164	9.3	0.72	1541	6.8	1.00	788	11.8	0.44
11	1195	10.5	0.72	1343	7.8	0.81	1048	13.2	0.63
12	1175	14.4	0.91	1477	8.6	1.00	872	20.3	0.81
13	1270	10.9	0.81	1285	8.5	0.81	1255	13.3	0.81
14	1131	5.8	0.72	1096	2.3	0.63	1165	9.2	0.81
15	*	*	*	*	*	*	*	*	*
Means	1249.25	9.6	0.80	1358.08	7.88	0.88	1033.00	11.29	0.73

Table 2f. Condition 6 (Warm)

Sub #	Score	Time	Accuracy	Letters Score	Letters Time	Letters Accuracy	Numbers Score	Numbers Time	Numbers Accuracy
1	1373	13.3	1.00	1368	13.3	1.00	1378	13.3	1.00
3	1409	3.7	0.81	1613	3.6	1.00	1206	3.8	0.63
4	1553	6.0	1.00	1600	4.4	1.00	1499	7.7	1.00
5	*	*	*	*	*	*	*	*	*
6	1274	4.5	0.72	1558	5.9	1.00	990	3.2	0.44
8	1406	11.6	1.00	1515	7.9	1.00	1297	15.4	1.00
9	1121	8.9	0.72	1245	8.8	0.81	998	8.9	0.63
10	1256	8.4	0.81	1586	4.9	1.00	926	11.8	0.63
11	1278	9.9	0.81	1485	8.9	1.00	1070	10.8	0.63
12	1287	12.4	0.91	1523	7.4	1.00	1051	17.4	0.81
13	1262	13.5	0.91	1276	9.4	0.81	1248	17.5	1.00
14	1295	5.2	0.81	1305	5	0.81	1284	5.5	0.81
15	1376	4.3	0.81	1595	4.2	1.00	1157	4.3	0.63
Means	1324.17	8.5	0.86	1472.42	6.98	0.95	1175.33	9.97	0.77

Tables 3a-b
CCAB - Marking Numbers

Table 3a. Condition 1 (Cold)

Sub #	Score	Total Time	Mean Time	% Hits	Interruption Task, Mean Time
1	1007	60.0	4.42	100	6.15
3	1269	55.5	2.73	100	3.88
4	1255	60.0	2.64	100	3.17
5	1392	56.7	3.73	100	4.05
6	842	60.0	4.79	100	5.80
8	1185	58.7	2.96	100	5.56
9	972	60.0	6.03	100	4.53
10	1424	49.0	2.46	100	3..8
11	1214	57.7	3.86	100	5.81
12	1081	60.0	3.29	100	5.48
13	1020	60.0	3.93	88	5.71
14	1327	57.7	2.67	100	4.87
15	1108	60.0	4.03	100	4.07
Means	1161.23	58.1	3.66	99.08	4.92

Table 3b. Condition 2 (Cold, Wet)

Sub #	Score	Total Time	Mean Time	% Hits	Interruption Task, Mean Time
1	1025	60.0	4.19	100	5.66
3	1273	55.5	3.04	100	3.80
4	1234	60.0	2.77	100	3.51
5	1433	56.4	3.5	100	4.37
6	1003	60.0	4.87	100	5.72
8	1241	60.0	2.95	100	3.76
9	1058	60.0	2.8	100	3.60
10	1431	50.0	2.42	86	4.50
11	1233	50.3	3.06	83	5.37
12	981	60.0	2.61	100	4.90
13	1541	55.9	2.82	100	3.61
14	1552	55.0	2.43	100	4.33
15	1236	60.0	3.36	100	3.45
Means	1249.31	57.2	3.14	97.62	4.35

Tables 3c-d
CCAB - Marking Numbers

Table 3c. Condition 3 (Cold, Wet, Fatigue)

Sub #	Score	Total Time	Mean Time	% Hits	Interruption Task, Mean Time
1	1088	60.0	3.11	100	4.85
3	*	*	*	*	*
4	1272	60.0	2.94	100	3.47
5	1023	60.0	3.48	88	5.52
6	824	60.0	5.7	100	6.86
8	1317	57.4	3.12	100	5.34
9	985	60.0	4.78	100	4.06
10	1148	60.0	2.63	100	4.64
11	1395	55.1	3.2	100	5.92
12	972	60.0	3.86	100	5.22
13	1324	54.3	2.63	100	4.43
14	1351	53.5	2.3	100	3.65
15	1166	60.0	4.13	100	3.87
Means	1155.42	58.4	3.49	99.00	4.82

Table 3d. Condition 4 (Cold, Wet, Exercise)

Sub #	Score	Total Time	Mean Time	% Hits	Interruption Task, Mean Time
1	1041	60.0	3.81	100	5.22
3	*	*	*	*	*
4	1235	60.0	2.91	100	4.43
5	1086	60.0	4.09	*	*
6	885	60.0	5.16	100	5.77
8	1230	60.0	2.5	100	3.84
9	1019	60.0	2.87	100	4.07
10	1590	50.3	1.95	100	3.61
11	1032	60.0	3.45	88	5.50
12	962	60.0	3.62	100	6.18
13	1318	55.6	2.33	100	3.87
14	1405	47.4	2.58	100	4.87
15	1402	58.4	2.76	100	3.53
Means	1183.75	57.6	3.17	98.91	4.63

Tables 3e-f
CCAB - Marking Numbers

Table 3e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Sub #	Score	Total Time	Mean Time	% Hits	Interruption Task, Mean Time
1	988	60.0	4.05	88	5.14
3	1189	60.0	2.87	100	4.50
4	1153	60.0	3.55	100	4.75
5	1327	56.9	6.73	100	5.30
6	817	60.0	5.48	75	6.02
8	1551	51.7	2.61	100	4.24
9	1147	60.0	5.06	100	4.27
10	1192	60.0	2.42	100	3.88
11	1360	51.4	3.05	100	5.95
12	1001	60.0	4.02	100	5.73
13	1172	60.0	2.47	100	4.65
14	1438	49.0	2.63	100	3.87
15					
Means	1194.58	57.4	3.75	96.92	4.86

Table 3f. Condition 6 (Warm)

Sub #	Score	Total Time	Mean Time	% Hits	Interruption Task, Mean Time
1	939	60.0	5.36	100	6.37
3	1394	53.8	3.38	100	4.02
4	1183	60.0	2.96	100	4.83
5	1083	60.0	3.73	88	4.66
6	995	60.0	4.19	100	5.68
8	1625	53.8	2.9	100	4.36
9	1110	60.0	4.48	100	3.40
10	1256	60.0	2.51	100	3.95
11	1523	55.2	3.21	100	4.40
12	1023	60.0	3.02	100	5.17
13	1216	58.4	2.84	100	4.88
14	1648	46.5	2.51	100	3.45
15	*	*	*	*	*
Means	1249.58	57.3	3.42	99.00	4.60

Tables 4a-c

CCAB - Numbers & Words

Table 4a. Condition 1 (Cold)

Sub #	Score	% Good Hits	Mean Time	Solved Try 1	Resp Time	Solved Try 2	Resp Time	Total Time	% Solved
1	1166	91.19%	0.47	3	43.2	¥	¥	43.2	100.00%
3	1148	96.11%	0.51	2	14	0	6.5	20.5	66.67%
4	1346	83.80%	0.33	3	27	¥	¥	27	100.00%
5	1090	73.75%	0.52	3	38.3	¥	¥	38.3	100.00%
6	1179	86.19%	0.46	3	40.5	¥	¥	40.5	100.00%
8	1367	85.24%	0.73	3	26.8	¥	¥	26.8	100.00%
9	840	88.69%	0.49	1	40.7	2	7.7	48.5	100.00%
10	1065	74.45%	0.46	2	28.1	1	8.6	36.7	100.00%
11	914	85.64%	0.35	2	32.8	0	0	52.8	66.67%
12	1155	68.89%	0.56	2	21.5	1	7	28.5	100.00%
13	1080	0.8306	0.59	2	32.6	1	4.2	36.8	100.00%
14	842	82.44%	0.47	1	25.6	1	16.7	42.3	66.67%
15	1113	88.38%	0.33	2	39.8	0	0	41.1	66.67%
Means	**1100.38**	**83.68%**	**0.48**	**2.31**	**31.61**	**0.75**	**6.34**	**37.15**	**89.74%**

Table 4b. Condition 2 (Cold, Wet)

Sub #	Score	% Good Hits	Mean Time	Solved Try 1	Resp Time	Solved Try 2	Resp Time	Total Time	% Solved
1	988	93.17%	0.48	2	43.3	1	4.6	47.9	100.00%
3	1485	96.67%	0.48	3	26	¥	¥	26	100.00%
4	1406	86.77%	0.4	3	24.4	¥	¥	24.4	100.00%
5	1314	87.58%	0.46	3	32.2	¥	¥	32.3	100.00%
6	1332	91.67%	0.5	3	33.2	¥	¥	33.2	100.00%
8	1235	79.56%	0.66	3	32.6	¥	¥	32.6	100.00%
9	1133	65.34%	0.59	3	30.8	¥	¥	30.8	100.00%
10	920	81.44%	0.48	1	28	1	6.9	34.9	66.67%
11	809	86.99%	0.37	2	37.3	0	0	57.4	66.67%
12	1307	83.08%	0.48	2	18.7	1	3.9	22.6	100.00%
13	729	84.27%	0.5	1	29.8	0	12.7	42.5	33.33%
14	1047	90.28%	0.42	2	39.7	1	3.5	43.2	100.00%
15	1086	76.98%	0.44	3	41.6	¥	¥	41.6	100.00%
Means	**1137.77**	**85.06%**	**0.49**	**2.38**	**32.12**	**0.67**	**5.27**	**36.11**	**89.74%**

Table 4c. Condition 3 (Cold, Wet, Fatigue)

Sub #	Score	% Good Hits	Mean Time	Solved Try 1	Resp Time	Solved Try 2	Resp Time	Total Time	% Solved
1	1261	88.89%	0.47	3	37.2	¥	¥	37.2	100.00%
3	*	*	*	*	*	*	*	*	*
4	1319	90.00%	0.51	3	33.2	¥	¥	33.2	100.00%
5	1158	88.82%	0.55	3	42.1	¥	¥	42.1	100.00%
6	881	80.84%	0.5	1	13.6	0	53.7	67.3	33.33%
8	1477	100.00%	0.46	3	28.7	¥	¥	28.7	100.00%
9	964	55.55%	0.37	2	20.8	1	5.5	26.3	100.00%
10	1099	86.14%	0.38	2	30.7	0	1.2	31.9	66.67%
11	858	82.47%	0.39	2	34.6	0	0	54.6	66.67%
12	885	62.89%	0.6	1	36.6	1	2	44.3	66.67%
13	1133	89.47%	0.55	2	24.4	0		44.4	66.67%
14	1378	33.33%	0.13	3	2.7	¥	¥	2.7	100.00%
15	1357	56.67%	0.42	3	15	¥	¥	15	100.00%
Means	**1147.50**	**76.26%**	**0.44**	**2.33**	**26.63**	**0.33**	**12.48**	**35.64**	**83.33%**

Tables 4d-f

CCAB - Numbers & Words

Table 4d. Condition 4 (Cold, Wet, Exercies)

Sub #	Score	% Good Hits	Mean Time	Solved Try 1	Resp Time	Solved Try 2	Resp Time	Total Time	% Solved
1	1083	90.74%	0.43	2	40.4	0	0	43.6	66.67%
3	*	*	*	*	*	*	*	*	*
4	1228	84.92%	0.35	3	37	¥	¥	37	100.00%
5	1268	77.81%	0.56	3	28.9	¥	¥	28.9	100.00%
6	1040	89.80%	0.45	2	41.3	1	2.8	44.2	100.00%
8	1329	85.84%	0.64	3	29.7	¥	¥	29.7	100.00%
9	1323	83.57%	0.38	3	28	¥	¥	28	100.00%
10	954	62.22%	0.6	1	21.4	2	9.4	30.8	100.00%
11	777	87.83%	0.42	1	31.7	1	5.1	56.8	66.67%
12	1017	66.62%	0.78	2	22	0	0	42	66.67%
13	862	84.90%	0.4	1	27.5	1	4	51.5	66.67%
14	1243	58.97%	0.45	2	10	1	7	17	100.00%
15	911	67.77%	0.53	1	9.8	2	23.1	32.9	100.00%
Means	1086.25	78.42%	0.50	2.00	27.31	1.00	6.43	36.87	88.89%

Table 4e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Sub #	Score	% Good Hits	Mean Time	Solved Try 1	Resp Time	Solved Try 2	Resp Time	Total Time	% Solved
1	1200	93.30%	0.38	3	41.3	¥	¥	41.3	100.00%
3	1230	89.16%	0.45	3	38.2	¥	¥	38.3	100.00%
4	990	79.08%	0.37	3	48.4	¥	¥	48.4	100.00%
5	1229	79.51%	0.37	3	33.2	¥	¥	33.2	100.00%
6	1126	76.27%	0.39	3	39	¥	¥	39	100.00%
8	1344	87.83%	0.7	3	29.4	¥	¥	29.5	100.00%
9	1216	77.38%	0.32	3	31.7	¥	¥	31.7	100.00%
10	1129	79.87%	0.48	2	25.8	1	5.2	31	100.00%
11	1056	0.8677	0.35	3	45.8	¥	¥	45.8	100.00%
12	1111	75.00%	0.7	2	29.6	0	1.1	30.7	66.67%
13	1015	88.04%	0.39	2	35.1	0	1.8	36.9	66.67%
14	1678	93.33%	0.62	3	7.6	¥	¥	7.6	100.00%
15	*	*	*	*	*	*	*	*	*
Means	1193.67	83.80%	0.46	2.75	33.76	0.20	2.03	34.45	94.44%

Table 4f. Condition 6 (Warm)

Sub #	Score	% Good Hits	Mean Time	Solved Try 1	Resp Time	Solved Try 2	Resp Time	Total Time	% Solved
1	1083	97.77%	0.46	2	27.7	0	0	47.7	66.67%
3	1294	90.74%	0.4	3	35.1	¥	¥	35.1	100.00%
4	1248	85.42%	0.55	3	36.8	¥	¥	36.8	100.00%
5	1410	87.50%	0.49	3	24.9	¥	¥	24.9	100.00%
6	1213	93.02%	0.5	3	41.1	¥	¥	41.1	100.00%
8	1326	91.41%	0.67	3	33.7	¥	¥	33.7	100.00%
9	1416	89.63%	0.41	3	26.2	¥	¥	26.2	100.00%
10	1165	82.22%	0.37	2	22.2	0	5.6	27.8	66.67%
11	877	87.72%	0.33	1	15.8	0	0	55.8	33.33%
12	1268	87.17%	0.61	3	34.8	¥	¥	34.8	100.00%
13	1098	78.45%	0.45	2	26	1	8.1	34.1	100.00%
14	921	87.22%	0.53	2	42.9	1	6.3	49.2	100.00%
15	833	63.40%	0.48	1	25.8	2	13.8	39.6	100.00%
Means	1165.54	86.28%	0.48	2.38	30.23	0.67	5.63	37.45	89.74%

CCAB - Route Planning

Table 5a. Condition 1 (Cold)

Sub #	Score	Total Time	Minimum/ Valid moves	Number Errors	Number Reversals	Mean Time
1	1063	35.9	1.50	0	0	12.97
3	878	43.0	0.96	1	4	7.60
4	1142	34.9	1.00	1	0	8.34
5	1302	21.2	1.00	0	0	4.86
6	930	44.9	1.14	1	3	11.40
8	1091	34.3	0.87	1	1	3.34
9	720	60.0	2.00	2	0	15.94
10	1420	11.2	1.00	0	0	2.77
11	1120	28.7	1.08	1	2	7.31
12	1121	40.0	0.83	1	2	7.69
13	1445	7.8	1.00	0	0	1.84
14	1338	19.6	1.00	0	0	4.70
15	1363	16.1	1.00	0	0	3.67
Means	1148.69	30.6	1.09	0.62	0.92	7.11

Table 5b. Condition 2 (Cold, Wet)

Sub #	Score	Total Time	Minimum/ Valid moves	Number Errors	Number Reversals	Mean Time
1	990	45.1	1.00	0	1	7.95
3	887	36.9	0.63	0	5	5.48
4	1171	33.3	1.00	1	0	7.87
5	1116	34.1	0.92	5	1	7.89
6	1059	34.7	1.22	1	1	9.45
8	769	47.9	1.87	0	0	32.24
9	1073	31.2	0.67	0	0	3.29
10	1062	31.7	1.50	1	1	13.08
11	1083	31.2	1.50	0	1	9.95
12	1162	25.7	0.76	0	0	4.82
13	1090	25.0	0.93	4	1	5.44
14	1348	18.7	1.00	0	0	4.45
15	1291	17.7	0.93	0	0	3.80
Means	1084.69	31.8	1.07	0.92	0.85	8.90

Table 5c. Condition 3 (Cold, Wet, Fatigue)

Sub #	Score	Total Time	Minimum/ Valid moves	Number Errors	Number Reversals	Mean Time
1	979	46.3	1.22	0	0	12.28
3						
4	1307	23.4	1.00	0	0	5.81
5	1141	33.0	0.90	0	0	7.28
6	843	55.0	0.92	4	3	9.67
8	1337	19.0	1.00	0	0	4.49
9	962	41.0	1.50	1	0	15.41
10	1244	23.4	0.94	0	1	5.03
11	1099	30.9	1.22	0	1	7.74
12	729	59.1	0.95	4	1	11.13
13	1422	10.4	1.00	0	0	2.49
14	1284	19.1	0.93	0	1	3.91
15	1036	28.8	0.80	2	4	4.69
Means	1115.25	32.5	1.03	0.92	0.92	7.49

Tables 5d-f

CCAB - Route Planning

Table 5d. Condition 4 (Cold, Wet, Exercies)

Sub #	Score	Total Time	Minimum/ Valid moves	Number Errors	Number Reversals	Mean Time
1	1116	29.1	1.50	0	0	11.47
3						
4	976	43.0	0.67	0	0	7.16
5	1405	13.6	1.00	0	0	3.49
6	1093	45.5	1.00	0	2	.9.03
8	1112	36.7	0.93	0	0	7.92
9	911	44.3	0.67	0	0	6.56
10	1330	25.6	2.33	4	0	7.74
11	1032	38.9	1.50	0	1	10.93
12	758	57.4	1.48	1	1	13.28
13	1445	8.1	1.00	0	0	1.97
14	1148	29.8	0.88	3	1	6.46
15	1133	23.7	0.88	2	3	4.38
Means	1121.58	33.0	1.15	0.83	0.67	7.40

Table 5e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Sub #	Score	Total Time	Minimum/ Valid moves	Number Errors	Number Reversals	Mean Time
1	1133	30.9	1.08	0	0	5.92
3	857	37.9	0.64	1	5	4.99
4	1213	31.9	1.00	1	0	7.95
5	1120	28.0	1.50	0	0	12.05
6	815	47.5	1.02	4	4	10.66
8	1264	22.2	4.00	0	0	4.78
9	1073	33.9	1.50	0	0	12.87
10	1198	30.0	1.00	0	0	6.93
11	1340	18.6	1.00	0	0	4.26
12	1067	36.8	0.80	1	1	7.32
13	1308	23.8	1.00	0	0	5.93
14	1394	13.4	1.00	0	0	3.12
15						
Means	1148.50	29.6	1.30	0.58	0.83	7.23

Table 5f. Condition 6 (Warm)

Sub #	Score	Total Time	Minimum/ Valid moves	Number Errors	Number Reversals	Mean Time
1	1072	37.4	1.22	1	0	11.54
3	821	41.5	0.80	1	4	5.88
4	1301	21.9	1.00	0	0	5.09
5	1354	17.5	1.00	0	0	4.12
6	1339	19.7	1.00	0	0	4.77
8	909	48.1	0.97	1	0	10.82
9	832	45.7	2.00	0	1	8.31
10	1373	16.3	1.00	0	0	3.91
11	1096	29.0	1.50	0	1	10.75
12	987	47.3	0.83	1	1	8.71
13	1388	14.1	1.00	1	0	3.31
14	1190	25.9	0.94	0	1	5.21
15	1202	20.6	0.87	2	2	4.41
Means	1143.38	29.6	1.07	0.54	0.77	6.68

Tables 6a-c

CCAB - Tower Puzzle

Table 6a. Condition 1 (Cold)

Sub #	Score	Total Time	Min/Act moves	% Done	Errors	Reversals	Mean Time
1	1016	37.1	1.04	66.70%	0	1	8.18
3	1272	34.6	0.82	80.60%	3	4	4.89
4	1817	25.3	0.95	100.00%	5	2	4.68
5	474	43.7	1.39	66.67%	6	3	4.31
6	1120	40.1	1.07	84.40%	2	3	4.34
8	2029	19.3	1	100.00%	0	0	3.88
9	1252	35.5	1.03	82.10%	2	3	6.37
10	1448	31.6	1	84.44%	3	2	6.04
11	673	46.7	1.1	69.00%	5	1	4.63
12	625	46.9	0.88	66.67%	0	4	7.62
13	*	*	*	*	*	*	*
14	1756	22	0.94	100.00%	0	0	4.48
15	820	38.3	0.63	100.00%	1	3	3.95
Means	1191.83	35.09	0.99	83.38%	2.25	2.17	5.28

Table 6b. Condition 2 (Cold, Wet)

Sub #	Score	Total Time	Min/Act moves	% Done	Errors	Reversals	Mean Time
1	1054	36.7	1.3	71.11%	0	1	7.09
3	1699	23	0.88	100.00%	2	0	4.93
4	1188	32.8	1.18	66.70%	3	3	3.62
5	1303	37.2	0.92	96.70%	4	0	5.77
6	1103	39.5	1.26	68.90%	3	3	3.88
8	554	50.1	1.91	59.10%	4	1	4.47
9	1413	31.8	0.91	100.00%	0	0	6.04
10	557	49.7	2	37.80%	2	4	13.88
11	1004	37.4	0.98	83.33%	4	0	5.86
12	1309	33.5	1.15	66.66%	0	2	4.94
13	877	44.7	0.86	94.90%	2	3	7.3
14	780	45.1	0.9	66.40%	3	2	4.69
15	1683	23.9	0.96	100.00%	0	1	9.21
Means	1117.23	37.34	1.17	77.82%	2.08	1.54	6.28

Table 6c. Condition 3 (Cold, Wet, Fatigue)

Sub #	Score	Total Time	Min/Act moves	% Done	Errors	Reversals	Mean Time
1	1261	33.1	1.5	66.66%	1	2	7.93
3	*	*	*	*	*	*	*
4	985	39.8	1.17	66.66%	3	3	4.41
5	1148	39.4	1.12	76.70%	5	3	6.82
6	638	49.1	1.69	37.80%	4	3	10.11
8	1354	35.3	0.84	100.00%	1	1	7.23
9	1272	35	0.92	94.90%	1	1	7.43
10	161	60	1.86	9.50%	9	8	9.5
11	778	46.5	0.75	66.66%	5	4	1.79
12	1019	42.5	1.07	66.66%	1	3	9.3
13	1285	38.7	0.88	100.00%	0	2	9.47
14	1707	20.3	0.91	100.00%	0	2	3.33
15	950	31.6	0.82	66.67%	0	3	5.4
Means	1046.50	39.28	1.13	71.02%	2.50	2.92	6.89

Tables 6d-f

CCAB - Tower Puzzle

Table 6d. Condition 4 (Cold, Wet, Exercise)

Sub #	Score	Total Time	Min/Act moves	% Done	Errors	Reversals	Mean Time
1	1385	33.3	0.94	95.60%	0	1	5.77
3	*	*	*	*	*	*	*
4	1238	39	0.9	77.77%	4	2	8.28
5	1156	38.1	0.97	87.20%	5	2	5.35
6	148	60	9	4.40%	2	2	12.8
8	1734	26.6	0.96	100.00%	0	1	4.31
9	1343	29.4	0.83	100.00%	0	3	5.6
10	1899	23.9	0.98	100.00%	0	1	8.24
11	349	53.4	0.96	69.00%	8	4	4.32
12	672	46.3	1.42	33.33%	6	4	5.8
13	653	49.9	0.76	66.66%	2	2	9.59
14	1284	30.3	1.21	66.67%	0	2	4.87
15	1214	29	0.73	100.00%	3	4	2.93
Means	1089.58	36.27	1.64	75.05%	2.50	2.33	6.49

Table 6e. Condition 5 (Cold, Wet, Exercise, Fatigue)

Sub #	Score	Total Time	Min/Act moves	% Done	Errors	Reversals	Mean Time
1	666	45.2	0.86	70.00%	0	1	3.48
3	706	47	1.01	48.70%	2	2	6.83
4	665	47.4	1.12	36.10%	5	6	5.6
5	1512	30.6	0.92	100.00%	2	1	5.49
6	895	50.8	0.96	97.00%	3	2	10.82
8	2009	19.7	10	100.00%	0	0	5.22
9	1193	34.4	1.1	66.66%	0	2	6.06
10	1365	35.7	1.12	84.40%	0	0	15.31
11	1334	*	*	*	*	*	*
12	1415	32.9	0.88	94.90%	0	1	5.9
13	428	51.7	1.06	33.33%	5	5	7.32
14	1878	20.7	1	100.00%	0	0	3.94
15	*	*	*	*	*	*	*
Means	1172.17	37.83	1.82	75.55%	1.55	1.82	6.91

Table 6f. Condition 6 (Warm)

Sub #	Score	Total Time	Min/Act moves	% Done	Errors	Reversals	Mean Time
1	804	45.6	1.25	61.10%	1	1	7.4
3	1183	36.9	0.78	100.00%	2	2	4.91
4	1257	35.6	0.82	100.00%	3	2	4.3
5	1216	34.4	1.15	66.67%	3	3	5.86
6	1255	37.3	1.02	84.44%	2	4	5.17
8	1525	29.6	0.89	100.00%	0	3	4.38
9	1417	31.5	0.92	100.00%	0	1	3.75
10	1279	36.7	0.92	84.40%	2	4	8.68
11	1136	31.8	0.88	90.50%	2	4	4.32
12	1246	39.3	0.88	100.00%	0	1	7.51
13	531	52.4	1.21	33.33%	7	4	11.85
14	1129	39.8	0.84	100.00%	2	3	1.53
15	935	32.5	0.8	66.66%	2	6	3.02
Means	1147.15	37.18	0.95	83.62%	2.00	2.92	5.59

Appendix VII

Table 1a. Heart Rate (beats/minute)
Cold (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	76	60	60	64	76	84	60	70	56	78	72	68	88	12.6
9	106	69	55	83	84	78	58	72	53	76	80	64	82	14.8
21	74	70	60	72	65	80	56	78	48	80	64	58	82	14.1
33	64	80	68	78	78	76	60	70	50	78	63	68	73	16.9
45	69	75	62	68	78	78	76	74	43	77	72	64	72	17.4
57	69	76	68	72	78	76	76	76	48	82	60	72	82	19.4
100	76	93	62	82	76	76	66	76	56	72	76	68	82	25.6
123	74	78	65	74	74	78	74	78	52	74	74	76	68	27.6
152	70	77	60	76	68	76	64	70	48	75	67	86	76	26.2

Table 1b. Heart Rate (beats/minute)
Cold/Wet (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	76	60	60	84	80	76	52	64	64	84	80	68	72	70.8
9	78	58	58	62	72	76	46	77	49	82	66	92	82	69.1
21	84	62	58	78	70	68	38	78	43	64	68	62	81	65.7
33	83	70	66	72	70	72	42	73	52	72	65	67	91	68.8
45	72	80	60	76	78	64	44	73	54	74	82	64	64	68.1
57	68	72	54	74	68	76	46	74	43	66	64	62	80	65.2
100	76	70	54	84	67	76	64	86	58	74	93	72	108	75.5
123	72	84	68	82	78	80	66	82	55	84	86	66	82	75.8
152	77	76	56	86	76	80	66	74	53	80	76	70	94	74.2

Table 1c. Heart Rate (beats/minute)
Cold/Wet/Fatigue (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	74	80	80	60	72	84	88	66	64	84	60	56	60	71.4
9	68	66	86	73	72	76	78	66	50	68	73	65	78	70.7
21	68	68	92	71	70	79	58	82	46	94	70	62	78	72.2
33	72	68	82	85	64	78	68	70	46	76	72	62	86	71.5
45	76	75	84	89	66	82	68	65	44	68	70	65	66	70.6
57	72	80	78	80	82	72	68	68	46	76	74	62	78	72.0
100	88	110	80	92	70	80	72	72	48	88	74	93	98	81.9
123	68	80	72	62	76	83	92	100	48	94	72	74	98	78.4
152	77	120	54	83	58	82	84	81	46	78	74	80	92	77.6

Table 1d. Heart Rate (beats/minute)
Cold/Wet/Exercise (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	76	60	60	60	72	76	50	72	50	84	72	72	80	68.0
9	72	72	64	64	60	75	56	74	48	78	69	84	82	69.1
21	142	152	163	156	160	120	152	154	145	162	147	156	135	149.5
33	82	94	98	92	84	98	68	102	66	112	85	94	94	89.9
45	135	150	159	152	152	123	154	145	145	156	148	161	147	148.2
57	80	92	82	78	84	92	52	94	64	84	73	98	90	81.8
100	78	108	76	72	62	86	64	88	58	106	72	90	70	79.2
123	82	78	72	76	68	96	68	82	58	92	70	85	90	78.2
152	80	104	80	78	66	86	80	85	58	94	65	82	84	80.2

Table 1e. Heart Rate (beats/minute)
Cold/Wet/Exercise/Fatigue (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	76	68	64	68	76	78	60	76	56	84	60	60	78	69.5
9	78	68	70	68	80	84	46	68	76	72	68	74	80	71.7
21	150	164	160	157	149	134	156	151	142	157	156	146	140	150.9
33	100	92	72		82	84	54	98	68	96	84	76	86	82.7
45	145	158	160	158	151	147	130	148	140	146	154	157	126	147.7
57	94	94	70	90	96	86	58	72	76	96	98	95	84	85.3
100	76	98	70	72	84	86	56	83	64	78	104	78	80	79.2
123	80	104	72	96	90	84	70	86	58	84	104	82	87	84.4
152	62	86	70	80	70	82	54	82	50	82	90	83	86	75.2

Table 1f. Heart Rate (beats/minute)
Warm (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	76	64	62	72	68	84	88	76	68	84	60	72	88	74.0
9	92	74	84	68	72	75	80	76	60	78	83	72	83	76.7
21	80	76	82	64	68	84	58	72	60	83	66	72	88	73.3
33	72	68	82	68	72	77	52	74	50	76	60	60	90	69.3
45	76	76	58	76	80	76	62	74	40	80	84	52	76	70.0
57	74	60	60	46	66	77	58	72	44	75	61	48	82	63.3
100	68	60	54	52	78	82	56	66	48	76	64	48	74	63.5
123	86	70	58	58	68	86	54	68	50	83	60	48	88	67.5
152	66	70	48	56	62	80	62	80	48	83	57	48	70	63.8

Table 2a. Systolic Blood Pressure (mmHg)
Cold (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	128	126	118	120	126	130	120	116	122	128	128	126	132	124.6
9	134	118	104	118	114	130	128	116	120	136	134	130	138	124.6
21	136	120	110	128	118	130	124	116	118	138	132	130	142	126.3
33	142	130	104	130	118	124	132	114	126	134	130	128	136	126.8
45	140	132	112	130	120	128	126	116	124	130	124	132	138	127.1
57	138	130	118	122	120	128	124		122	140	122	128	136	127.3

Table 2b. Systolic Blood Pressure (mmHg)
Cold/Wet (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	132	126	112	122	130	128	124	112	118	128	122	130	128	124.0
9	132	124	114	120	126	126	124	116	110	130	122	130	124	122.9
21	132	124	116	124	134	124	122	112	114	128	120	136	126	124.0
33	134	122	114	122	138	124	132	120	124	126	124	128	128	125.8
45	138	122	130	120	134	120	122	120	126	124	132	132	130	[illegible]
57	138	124	108	118	124	124	124	120	132	124	124	128	126	124.2

Table 2c. Systolic Blood Pressure (mmHg)
Cold/Wet/Fatigue (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	130	110	124	128	126	130	128	112	132	130	128	110	132	124.6
9	132	106	124	122	124	132	128	112	132	128	136	110	122	123.7
21	126	108	128	128	132	130	128	106	128	130	128	114	128	124.2
33	134	112	118	126	134	132	128	104	126	130	12[illegible]	112	128	123.8
45	134	114	122	126	130	130	128	108	122	132	130	116	124	124.3
57	142	112	118	126	130	132	128	104	122	132	126	114	130	124.3

Table 2d. Systolic Blood Pressure (mmHg)
Cold/Wet/Exercise (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	128	120	118	122	128	132	132	132	120	134	126	128	110	125.4
9	128	124	122	128	124	128	136	118	118	132	118	128	112	124.3
21	170	164	162	132	172	178	174	166	168	174	172	174	154	166.2
33	128	126	120	122	124	128	130	120	126	138	132	128	122	126.5
45	172	168	168	128	170	168	176	164	166	182	174	174	160	166.9
57	132	122	118	130	124	122	134	118	114	142	130	128	122	125.8

Table 2e. Systolic Blood Pressure (mmHg)
Cold/Wet/Exercise/Fatigue (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	126	118	118	122	114	124	122	128	114	130	132	122	120	122.3
9	124	130	134	124	112	134	118	118	112	128	128	126	120	123.7
21	156	166	165	168	120	178	168	158	168	172	172	170	150	162.4
33	128	120	128		110	130	126	128	126	136	132	124	122	125.8
45	160	174	168		120	180	164	164	170	172	168	172	170	165.2
57	134	118	136	122	110	132	118	124	126	142	130	126	124	126.3

Table 2f. Systolic Blood Pressure (mmHg)
Warm (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	122	118	110	118	122	132	124	122	128	124	130	132	116	122.9
9	122	120	108	118	128	132	120	124	128	124	130	134	124	124.0
21	122	118	110	120	130	132	118	124	118	124	128	124	120	122.2
33	124	120	110	116	128	128	112	124	114	124	128	128	122	121.4
45	122	122	106	124	124	126	124	122	114	124	128	134	120	122.3
57	120	120	104	122	124	126	122	124	118	130	124	124	118	121.2

Table 3a. Diastolic Blood Pressure (mmHg)
Cold (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	74	66	64	68	64	74	70	66	66	74	62	76	78	69.4
9	78	64	60	66	62	72	70	64	68	76	68	76	80	69.5
21	80	70	60	66	64	70	72	66	62	78	68	76	78	70.0
33	80	68	64	66	64	70	70	66	68	74	70	72	72	69.5
45	82	72	64	64	62	74	68	66	68	74	70	72	82	70.6
57	84	68	68	68	64	72	70		66	82	68	72	80	71.8

Table 3b. Diastolic Blood Pressure (mmHg)
Cold/Wet (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	76	66	62	66	70	72	66	64	64	78	64	72	72	68.6
9	72	66	66	70	70	72	70	64	68	80	70	70	72	70.0
21	74	68	66	70	70	72	70	64	66	78	66	76	72	70.2
33	70	68	66	70	70	70	70	68	70	74	68	70	74	69.8
45	78	68	64	68	72	70	64	68	64	70	70	72	72	69.2
57	80	68	64	68	68	72	66	66	72	72	68	72	74	70.0

Table 3c. Diastolic Blood Pressure (mmHg)
Cold/Wet/Fatigue (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	72	70	66	78	70	76	70	60	68	72	68	66	68	69.5
9	78	64	66	78	70	76	70	60	68	70	76	70	68	70.3
21	84	72	70	74	70	76	70	60	70	70	70	72	68	71.2
33	84	74	68	70	72	76	72	58	66	70	70	70	68	70.6
45	80	72	70	70	70	78	70	70	66	72	68	78	68	71.7
57	82	68	68	80	72	76	66	80	68	72	74	76	68	73.1

Table 3d. Diastolic Blood Pressure (mmHg)
Cold/Wet/Exercise (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	72	66	62	60	66	72	72	68	62	70	66	74	70	67.7
9	70	66	64	74	68	72	80	68	60	70	66	70	74	69.4
21	72	64	60	80	72	68	74	66	62	74	64	68	80	69.5
33	72	66	62	72	68	70	76	70	60	76	66	74	76	69.8
45	72	66	60	76	72	70	74	66	66	76	64	76	78	70.5
57	78	66	62	78	66	70	76	68	62	76	64	72	80	70.6

Table 3e. Diastolic Blood Pressure (mmHg)
Cold/Wet/Exercise/Fatigue (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	70	72	66	64	68	72	70	64	62	74	70	68	78	69.1
9	72	70	66	70	74	78	64	64	64	78	66	66	80	70.2
21	70	72	70	68	72	76	70	64	60	72	66	64	70	68.8
33	74	70	68		68	78	70	68	62	74	70	68	82	71.0
45	68	72	68		70	74	70	66	64	68	70	64	76	69.2
57	74	68	66	68	68	78	72	66	62	74	68	68	70	69.4

Table 3f. Diastolic Blood Pressure (mmHg)
Warm (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	70	64	64	66	64	78	68	68	64	66	64	72	68	67.4
9	70	70	60	66	64	78	70	68	64	72	64	72	70	68.3
21	70	70	64	70	64	78	70	68	62	68	68	76	70	69.1
33	70	70	66	66	64	76	72	68	64	68	66	76	72	69.1
45	70	72	64	70	68	76	72	68	66	68	66	78	70	69.8
57	72	70	58	68	68	78	68	68	64	70	64	76	70	68.8

Table 4a. Minute Ventilation (liters/minute)
Cold (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	10.2	10.4	11.6	13.0	14.7	17.4	11.9	10.5	11.9	20.3	11.0	9.6	12.0	12.6
9	8.9	10.9	17.8	19.8	17.6	15.1	9.9	14.4	18.8	19.9	16.7	10.4	12.1	14.8
21	8.5	13.0	13.1	19.5	16.9	14.1	10.2	13.2	12.6	25.7	15.6	9.0	12.6	14.1
33	7.7	16.2	24.4	24.8	20.9	18.8	12.8	10.9	19.6	26.1	17.8	9.2	10.7	16.9
45	12.4	14.0	20.0	20.1	21.1	28.4	12.8	12.1	17.5	25.6	18.9	11.2	12.3	17.4
57	16.0	19.3	21.9	20.8	16.6	30.7	23.5	13.6	15.9	27.7	17.0	15.0	14.2	19.4
100	19.2	25.8	21.3	35.5	19.9	32.5	45.0	19.0	21.9	32.5	25.5	15.4	18.8	25.6
123	16.0	25.0	22.7	40.3	25.2	41.7	49.3	18.0	19.2	30.3	26.7	28.0	16.4	27.6
152	10.9	15.3	21.4	35.9	21.8	48.1	40.3	30.1	20.0	26.3	23.9	28.3	18.1	26.2

Table 4b. Minute Ventilation (liters/minute)
Cold/Wet (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	8.8	10.4	13.5	16.9	14.5	13.8	9.6	15.1	10.8	19.8	11.6	13.4	13.6	13.2
9	10.2	8.8	13.3	19.6	15.7	7.9	13.1	13.6	19.9	26.4	14.4	13.9	14.0	14.7
21	9.9	15.4	17.6	22.8	14.1	10.3	13.5	10.7	26.2	21.7	13.0	14.7	11.3	15.5
33	13.3	15.0	16.8	29.3	15.0	10.7	8.9	16.0	15.1	21.7	16.7	14.0	9.5	15.5
45	16.3	19.2	15.1	27.3	15.6	14.2	13.6	14.4	18.3	20.2	14.6	12.2	19.6	17.0
57	21.5	15.9	17.3	27.9	21.3	14.5	19.4	18.5	14.7	31.7	15.5	14.1	19.7	19.4
100	32.6	19.9	26.5	47.9	25.4	39.6	37.5	20.6	19.0	35.5	37.2	18.4	31.6	30.1
123	36.3	18.8	22.6	48.5	26.1	32.9	51.5	26.5	19.8	42.3	36.3	18.9	19.1	30.7
152	35.8	17.6	25.9	52.4	22.6	37.0	40.7	22.0	21.7	36.8	28.6	16.0	22.4	29.2

Table 4c. Minute Ventilation (liters/minute)
Cold/Wet/Fatigue (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	17.0	11.3	11.6	13.7	14.1	11.6	11.1	18.8	11.5	29.9	12.5	14.2	10.2	14.4
9	7.8	13.2	20.4	16.5	16.8	13.0	10.9	18.1	12.4	25.2	15.3	17.5	9.0	15.1
21	7.4	13.4	32.0	17.5	12.5	13.6	11.5	13.9	16.0	23.9	16.6	12.8	12.9	15.7
33	12.2	17.6	28.6	19.3	13.9	20.6	11.8	13.7	16.2	26.4	15.4	14.9	11.5	17.1
45	14.0	18.2	27.8	21.5	15.7	21.4	15.7	14.4	19.1	24.3	15.5	19.5	15.7	18.7
57	16.8	16.3	25.3	24.6	20.8	20.6	16.5	18.8	18.4	28.1	20.5	17.4	19.4	20.3
100	26.3	63.4	24.2	39.5	22.7	25.3	26.2	37.0	19.8	33.9	26.3	21.7	26.7	30.2
123	24.7	22.9	24.0	35.7	33.3	35.5	32.9	28.6	21.2	43.2	22.5	22.6	24.8	28.6
152	19.7	24.4	25.7	33.3	28.5	34.1	40.9	31.5	23.0	32.9	21.7	29.9	25.0	28.5

Table 4d. Minute Ventilation (liters/minute)
Cold/Wet/Exercise (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	8.8	10.4	11.9	19.7	11.9	18.2	7.6	11.5	21.6	40.6	11.8	15.3	10.6	15.4
9	8.5	11.5		23.9	11.2	17.0	11.7	12.8	26.3	36.1	12.9	15.3	11.6	16.6
21	64.8	49.2	82.8	67.6	67.2	56.3	70.0	63.7	52.9	69.0	79.0	65.3	61.1	65.3
33	9.0	13.0		15.4	15.0	19.5	15.0	17.5	16.0	30.7	17.2	13.4	12.0	16.1
45	58 1	56.2		80.9	46.1	48.7	64.9	53.7	57.9	49.8	67.8	65.2	53.6	58.6
57	9.9	13.9	21.7	18.2	16.5	23.3	14.3	15.5	12.3	32.0	13.1	11.3	21.3	17.2
100	22.3	24.7	33.9	40.8	19.2	41.3	48.9	32.9	25.4	37.7	19.9	27.3	27.8	30.9
123	25.4	20.9	28.7	51.2	23.0	48.6	52.2	19.1	24.5	37.8	20.6	32.9	26.7	31.7
152	20.0	24.6	32.6	55.1	22.4	37.4	47.1	21.2	25.9	44.4	16.5	37.8	22.5	31.3

Table 4e. Minute Ventilation (liters/minute)
Cold/Wet/Exercise/Fatigue (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	10.5	10.5	14.3	29.4	11.4	17.4	11.5	10.7	11.7	22.9	10.5	14.0	10.6	14.3
9	10.6	14.3	15.3	24.6	19.6	17.6	6.8	12.4	14.9	23.3	12.4	15.2	8.5	15.0
21	67.5	62.6	78.3		69.6	62.5	46.0	66.9	60.3	72.3	59.3	61.2	54.5	63.4
33	9.3	12.6	15.0		18.6	14.4	9.0	12.7	12.3	17.3	17.2	11.6	14.2	13.7
45	54.8	55.1	74.4		75.8	37.8	54.2	57.6	50.7	49.8	47.9	53.8	50.9	55.2
57	9.9	13.3	13.0	23.7	21.9	19.8	10.0	9.3	10.2	27.5	13.9	12.5	15.0	15.4
100	18.4	25.3	23.2	32.3	58.9	35.8	18.0	24.5	26.7	31.0	28.6	22.5	25.6	28.5
123	19.5	25.9	24.5	44.0	48.6	44.0	25.6	24.5	22.6	33.6	31.0	26.1	22.8	30.2
152	20.8	18.1	34.6	51.1	40.0	45.6	32.0	18.7	18.7	26.3	29.6	24.8	23.2	29.5

Table 4f. Minute Ventilation (liters/minute)
Warm (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	14.1	11.4	11.3	15.6	12.2	13.1	10.2	10.5	10.4	31.6	15.7	9.6	11.7	13.7
9	10.2	10.4	11.3	11.9	11.9	9.7	9.3	8.8	9.1	28.2	13.5	9.1	19.9	12.6
21	7.2	11.0	10.6	12.5	9.9	9.4	11.0	13.2	11.1	16.0	9.5	8.7	12.9	11.0
33	6.5	11.5	11.7	10.3	9.6	10.0	8.6	10.0	6.2	18.7	11.3	8.8	9.6	10.2
45	6.2	9.4	15.4	9.6	8.2	9.3	8.7	8.7	11.4	15.9	8.9	8.7	12.0	10.2
57	11.0	11.6	10.2	13.4	11.6	9.4	8.6	11.0	9.0	19.1	12.7	9.0	12.1	11.5
100	10.1	10.2	9.1	10.2	9.4	12.2	10.1	9.6	8.8	19.9	10.4	8.9	10.2	10.7
123	8.9	13.7	11.0	11.7	9.1	14.1	10.4	11.1	9.1	18.7	9.2	10.1	11.9	11.5
152	9.4	12.0	12.7	14.4	7.5	11.3	10.6	10.1	8.1	22.9	7.3	10.1	7.9	11.1

Table 5a. Respiration Rate (breaths/minute)
Cold (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	11	18	9	19	17	16	10	16	12	15	11	15	12	13.9
9	10	14	14	19	15	12	13	21	17	18	14	12	12	14.7
21	10	13	11	21	16	10	11	17	14	19	14	13	12	13.9
33	7	16	15	19	12	13	11	16	16	18	12	10	10	13.5
45	8	15	13	21	16	12	15	14	16	20	14	11	9	14.2
57	9	13	15	22	10	12	13	14	14	20	15	11	10	13.7
100	8	22	14	21	13	15	17	15	15	19	15	15	12	15.5
123	8	23	17	23	13	12	18	16	16	17	16	12	11	15.5
152	6	15	17	23	15	13	20	21	16	14	15	13	12	15.4

Table 5b. Respiration Rate (breaths/minute)
Cold/Wet (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	10	16	18	19	15	13	15	18	9	22	10	13	10	14.5
9	11	12	17	18	14	10	13	20	17	14	14	8	10	13.7
21	9	15	17	21	12	10	19	17	15	19	14	13	9	14.6
33	10	15	14	21	15	9	15	19	16	20	15	12	7	14.5
45	10	11	16	22	15	12	17	18	18	20	13	13	10	15.0
57	11	17	16	17	12	14	23	20	13	19	11	13	12	15.2
100	13	19	15	26	11	15	20	12	15	21	9	12	15	15.6
123	13	18	10	24	16	10	29	18	14	21	16	14	14	16.7
152	12	18	16	28	15	10	27	19	15	17	14	13	10	16.5

Table 5c. Respiration Rate (breaths/minute)
Cold/Wet/Fatigue (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	16	19	15	18	12	14	15	12	16	20	12	16	10	15.0
9	10	15	17	18	14	16	18	19	15	21	14	17	10	15.7
21	9	17	12	21	14	14	13	20	17	20	16	16	13	15.5
33	8	15	21	18	12	13	19	15	18	19	12	12	10	14.8
45	9	19	24	20	9	12	20	15	17	19	13	11	13	15.5
57	9	18	24	18	18	15	21	19	16	21	15	13	10	16.7
100	11	29	19	24	12	13	22	20	17	27	16	7	13	17.7
123	9	20	21	24	16	13	23	17	19	25	13	14	20	18.0
152	7	21	15	21	14	13	23	18	15	15	10	13	13	15.2

Table 5d. Respiration Rate (breaths/minute)
Cold/Wet/Exercise (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	9	14	15	18	13	14	9	8	15	20	10	15	10	13.1
9	11	15		24	14	15	16	17	20	18	11	14	10	15.4
21	26	27	37	32	26	20	27	33	20	35	24	28	20	27.3
33	8	17		20	17	17	19	24	14	21	11	13	11	16.0
45	26	31		32	16	19	28	27	23	30	25	27	23	25.6
57	9	17	18	18	19	16	17	17	14	20	13	13	20	16.2
100	8	18	19	19	15	12	30	21	14	24	14	11	17	17.1
123	10	18	22	26	17	16	31	12	16	26	13	14	15	18.2
152	7	23	18	25	12	10	29	14	17	26	13	15	17	17.4

Table 5e. Respiration Rate (breaths/minute)
Cold/Wet/Exercise/Fatigue (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	10	16	16	21	13	12	10	14	12	17	10	13	9	13.3
9	12	16	12	21	16	12	11	13	15	14	11	15	10	13.7
21	27	29	33		26	19	19	22	22	33	24	26	19	24.9
33	12	14	17		20	12	18	12	12	15	10	16	14	14.3
45	21	32	33		23	13	18	30	24	29	21	22	22	24.0
57	9	18	15	23	22	14	14	15	7	16	12	17	10	14.8
100	8	18	16	25	20	12	18	14	19	21	18	13	14	16.6
123	8	18	19	26	21	13	21	12	17	16	17	14	14	16.6
152	7	18	22	26	18	11	21	14	12	17	17	15	13	16.2

Table 5f. Respiration Rate (breaths/minute)
Warm (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	10	13	11	20	14	11	15	13	10	18	11	14	12	13.2
9	10	17	14	16	15	14	15	13	12	17	11	13	12	13.8
21	9	18	16	18	13	13	12	18	14	18	9	11	9	13.7
33	11	21	14	18	12	11	11	12	8	22	13	12	10	13.5
45	9	17	12	14	11	13	10	14	10	16	11	15	11	12.5
57	10	20	16	14	15	10	15	15	13	22	15	14	14	14.8
100	10	14	13	13	12	8	18	17	11	21	9	13	11	13.1
123	9	21	11	14	12	13	17	11	11	17	9	12	8	12.7
152	8	20	14	19	15	13	16	15	12	18	10	15	9	14.2

Table 6a. Volume of CO_2 Expired (VCO_2) (liters/minute)
Cold (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	0.44	0.31	0.32	0.39	0.52	0.47	0.45	0.40	0.43	0.58	0.39	0.32	0.43	0.42
9	0.44	0.40	0.51	0.62	0.58	0.47	0.38	0.49	0.64	0.55	0.60	0.38	0.46	0.50
21	0.39	0.54	0.43	0.57	0.56	0.46	0.36	0.53	0.49	0.72	0.55	0.31	0.38	0.48
33	0.38	0.65	0.76	0.82	0.71	0.58	0.39	0.43	0.76	0.74	0.61	0.32	0.39	0.58
45	0.61	0.51	0.63	0.82	0.81	0.92	0.35	0.48	0.68	0.66	0.68	0.47	0.45	0.62
57	0.80	0.79	0.69	0.78	0.61	0.92	0.77	0.53	0.67	0.69	0.59	0.59	0.55	0.69
100	1.01	0.95	0.76	1.16	0.76	1.06	1.09	0.83	0.96	0.82	0.96	0.66	0.74	0.90
123	0.82	0.96	0.76	1.22	0.90	1.11	1.16	0.81	0.84	0.93	0.97	1.06	0.66	0.94
152	0.61	0.57	0.59	1.16	0.84	1.10	1.03	1.16	0.78	0.76	0.89	0.90	0.72	0.85

Table 6b. Volume of CO_2 Expired (VCO_2) (liters/minute)
Cold/Wet (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	0.34	0.30	0.40	0.46	0.52	0.48	0.30	0.50	0.33	0.46	0.47	0.47	0.42	0.42
9	0.39	0.32	0.34	0.55	0.53	0.31	0.43	0.43	0.62	0.68	0.55	0.57	0.46	0.47
21	0.39	0.63	0.58	0.61	0.48	0.41	0.40	0.36	0.77	0.32	0.53	0.53	0.38	0.49
33	0.49	0.62	0.60	0.71	0.55	0.42	0.27	0.49	0.48	0.45	0.68	0.51	0.31	0.51
45	0.62	0.81	0.50	0.66	0.58	0.56	0.42	0.53	0.57	0.21	0.57	0.49	0.63	0.55
57	0.78	0.63	0.61	0.61	0.81	0.51	0.58	0.63	0.52	0.75	0.64	0.51	0.74	0.64
100	1.16	0.77	0.84	1.14	1.02	1.24	1.12	0.87	0.73	1.03	1.59	0.71	1.32	1.04
123	1.27	0.78	0.74	1.23	0.99	1.18	1.29	1.07	0.76	1.23	1.35	0.77	0.72	1.03
152	1.25	0.70	0.71	1.14	0.93	1.23	0.94	0.88	0.76	0.97	1.25	0.60	0.76	0.93

Table 6c. Volume of CO_2 Expired (VCO_2) (liters/minute)
Cold/Wet/Fatigue (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	0.35	0.31	0.28	0.43	0.56	0.34	0.42	0.49	0.48	0.75	0.45	0.45	0.43	0.44
9	0.28	0.42	0.51	0.48	0.52	0.39	0.43	0.46	0.45	0.76	0.54	0.51	0.32	0.47
21	0.30	0.47	0.74	0.55	0.42	0.44	0.43	0.37	0.61	0.72	0.63	0.39	0.47	0.50
33	0.46	0.72	0.66	0.60	0.48	0.59	0.44	0.46	0.63	0.78	0.62	0.52	0.41	0.57
45	0.52	0.62	0.63	0.72	0.64	0.66	0.58	0.44	0.70	0.68	0.65	0.63	0.65	0.62
57	0.63	0.57	0.59	0.78	0.77	0.61	0.64	0.61	0.71	0.81	0.83	0.63	0.78	0.69
100	1.22	1.67	0.73	1.05	0.77	0.86	1.02	1.01	0.84	1.14	1.22	0.89	1.06	1.04
123	1.06	0.87	0.76	1.11	0.92	1.08	1.16	0.93	0.90	1.52	0.99	0.82	0.97	1.00
152	0.94	0.81	0.68	1.11	0.78	1.15	1.06	0.95	1.01	1.02	0.94	0.99	0.87	0.95

Table 6d. Volume of CO_2 Expired (VCO_2) (liters/minute)
Cold/Wet/Exercise (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	0.37	0.33	0.28	0.54	0.42	0.50	0.26	0.36	0.59	0.79	0.51	0.47	0.35	0.44
9	0.32	0.40		0.61	0.36	0.48	0.35	0.40	0.64	0.70	0.54	0.51	0.26	0.46
21	2.96	1.49	2.97	2.78	2.81	2.18	2.91	2.36	2.30	2.26	3.50	2.27	2.55	2.56
33	0.37	0.39		0.47	0.42	0.45	0.45	0.44	0.55	0.64	0.85	0.26	0.25	0.46
45	2.50	2.11		3.43	1.99	1.69	2.61	2.02	2.65	1.73	2.80	2.27	2.31	2.34
57	0.42	0.40	0.54	0.58	0.47	0.53	0.41	0.44	0.38	0.64	0.48	0.36	0.53	0.48
100	0.89	0.89	1.04	1.19	0.70	0.88	1.09	0.80	1.02	1.16	0.79	0.86	0.97	0.94
123	1.02	0.73	0.93	1.20	0.66	1.02	1.11	0.77	0.94	1.07	0.81	1.25	0.94	0.96
152	0.87	0.84	0.94	1.27	0.86	0.91	0.98	0.90	0.93	1.30	0.64	1.06	0.79	0.94

Table 6e. Volume of CO_2 Expired (VCO_2) (liters/minute)
Cold/Wet/Exercise/Fatigue (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	0.45	0.29	0.45	0.76	0.38	0.54	0.39	0.39	0.48	0.62	0.41	0.52	0.46	0.47
9	0.45	0.45	0.46	0.75	0.58	0.59	0.24	0.34	0.54	0.70	0.54	0.50	0.37	0.50
21	3.19	2.25	2.95		2.79	2.27	2.06	2.75	2.83	2.50	2.87	2.40	2.67	2.63
33	0.38	0.39	0.41		0.42	0.44	0.32	0.38	0.46	0.38	0.65	0.32	0.54	0.42
45	2.44	1.94	2.80		2.96	1.48	1.79	2.36	2.36	1.70	2.34	2.12	2.32	2.21
57	0.39	0.40	0.32	0.68	0.49	0.57	0.35	0.30	0.39	0.75	0.56	0.36	0.56	0.47
100	0.80	0.93	0.72	1.12	1.25	0.97	0.62	0.83	1.04	0.99	1.36	0.81	1.00	0.96
123	0.85	0.99	0.84	1.37	1.08	1.08	0.75	0.91	0.90	1.06	1.39	0.99	0.88	1.00
152	0.87	0.70	0.92	1.33	1.03	1.20	0.80	0.78	0.79	0.83	1.33	0.79	1.03	0.95

Table 6f. Volume of CO_2 Expired (VCO_2) (liters/minute)
Warm (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
0	0.51	0.37	0.34	0.50	0.45	0.58	0.33	0.33	0.34	0.83	0.69	0.30	0.26	0.45
9	0.39	0.33	0.29	0.31	0.45	0.36	0.27	0.22	0.27	0.68	0.49	0.30	0.29	0.36
21	0.27	0.34	0.30	0.33	0.37	0.32	0.35	0.31	0.36	0.41	0.35	0.27	0.16	0.32
33	0.23	0.35	0.32	0.30	0.36	0.24	0.25	0.27	0.21	0.45	0.39	0.27	0.06	0.28
45	0.23	0.28	0.41	0.27	0.30	0.33	0.28	0.24	0.40	0.42	0.34	0.27	0.25	0.31
57	0.41	0.37	0.29	0.41	0.43	0.35	0.28	0.34	0.30	0.53	0.42	0.29	0.19	0.35
100	0.39	0.31	0.21	0.29	0.33	0.37	0.32	0.22	0.31	0.48	0.38	0.28	0.16	0.31
123	0.39	0.43	0.26	0.34	0.33	0.46	0.30	0.34	0.37	0.48	0.32	0.32	0.21	0.35
152	0.41	0.36	0.34	0.40	0.26	0.34	0.29	0.29	0.26	0.59	0.26	0.28	0.08	0.32

Appendix VIII
Shivering Intensity in RMS voltages

Table 1a. Trapezius
Cold Condition (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	36	26	12	15	22	14	30	30	29	12	40	50	25	26.2
22	39	28	15	12	38	13	21	44	22	25	35	19	24	25.8
33	37	57	24	16	31	12	33	38	16	23	32	52	22	30.2
45	42	43	35	13	36	16	42	41	31	11	35	61	18	32.6
57	43	30	22	15	34	51	21	36	17	14	32	53	34	30.9
100	56	50	42	28	51	19	79	48	44	26	51	28	26	42.2
123	65	53	59	25	47	15	53	42	46	37	27	62	24	42.7
155	51	49	37	28	45	15	11	46	42	28	52	54	24	37.1

Table 1b. Trapezius
Cold/wet Condition (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	24	56	18	13	28	14	20	20	79	37	36	45	28	32.2
22	34	25	25	14	34	20	16	35	76	14	19	31	22	28.1
33	32	32	34	33	34	18	16	35	68	22	35	46	19	32.6
45	32	30	29	17	35	14	16	29	77	19	28	48	19	30.2
57	37	25	28	21	36	19	15	23	74	15	28	60	12	30.2
100	54	43	56	28	45	28	34	45	86	36	82	58	23	47.5
123	58	34	51	50	51	17	32	44	88	25	85	63	68	51.2
155	65	35	58	53	72	24	37	39	109	57	88	64	21	55.5

Table 1c. Trapezius
Cold/wet/fatigue Condition (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	32	41	18	40	35	17	14	22	15	26	37		16	26.1
22	37	32	43	33	22	18	13	24	22	32	30		18	27.0
33	38	54	54	20	45	19	21	23	24	21	24		27	30.8
45	41	27	49	14	43	21	20	27	27	19	24		20	27.7
57	47	40	27	44	52	15	13	30	42	27	34		17	32.3
100	60	85	32	32	79	107	37	34	51	49	31		25	51.8
123	70	63	57	35	82	17	41	31	39	53	64		32	48.7
155	59	62	71	61	96	28	46	33	32	53	66		29	53.0

Table 1d. Trapezius
Cold/wet/exercise Condition (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	38	51	18	17	20	13	41	33	45	29	40	33	18	30.5
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	32	17	13	21	24	13	25	23	18	41	40	37	17	24.7
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	36	63	38	16	24	20	21	27	26	14	25	26	18	27.2
100	53	79	55	30	37	31	55	36	39	49	47	74	19	46.5
123	55	94	50	34	57	22	31	36	85	35	30	77	16	47.8
155	57	57	59	34	49	57	57	46	100	37	42	90	31	55.1

Table 1e. Trapezius
Cold/wet/exercise/fatigue Condition (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	34	55	16	17	27	14	25	19	52	17	35	49	20	29.2
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	31	18	13	13	26	17	31	37	14	16	22	29	26	22.5
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	36	23	14	15	15	16	22	24	13	14	47	55	21	24.2
100	44	56	29	14	45	17	46	51	109	19	76	75	26	46.7
123	48	62	32	32	56	14	46	43	67	27	61	68	30	45.1
155	67	39	29	51	54	27	48	37	50	32	41	73	25	44.1

Note: Data missing from the 22 and 45 minute times is due to the fact that EMGs were not monitored during exercise periods.

Table 1f. Trapezius
Warm Condition (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	9	14	18	11	13	11	21	14	13	28	32		12	16.3
22	9	24	11	12	11	9	15	16	42	23	12	18	13	16.5
33	9	2	11	12	10	9	17	11	16	17	13	21	19	12.8
45	16	11	10	11	14	11	13	11	12	14	9	19	11	12.5
57	9	12	10	11	10	9	39	10	17	13	10	18	17	14.2
100	17	13	11	19	15	11	12	10	27	13	12		12	14.3
123	29	12	16	23	17	11	22	12	20	14	10	13	18	16.7
155	19	13	12	20		12	12	10	26	19	13	17	14	15.6

Table 2a. Pectoralis
Cold Condition (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	13	12	9	17	22	12	13	13	12	11	11	12	14	13.2
22	11	15	9	14	51	12	13	13	14	25	11	12	13	16.4
33	13	28	18	17	31	12	13	14	17	26	10	15	13	17.5
45	13	19	23	16	47	14	14	24	19	12	10	14	13	18.3
57	12	17	13	14	22	19	15	22	16	14	11	16	17	16.0
100	16	35	26	18	36	19	17	14	21	18	11	16	17	20.3
123	17	30	34	21	26	18	14	15	22	23	14	20	12	20.5
155	15	20	16	20	20	17	5	20	19	19	12	17	15	16.5

Table 2b. Pectoralis
Cold/wet Condition (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	10	15	13	15	29	16	21	12	15	19	15	15	12	15.9
22	11	17	16	14	29	20	19	14	19	14	16	14	11	16.5
33	12	20	17	34	31	19	19	12	23	17	28	15	15	20.2
45	11	19	16	17	33	20	17	15	16	17	16	14	11	17.1
57	12	16	18	15	28	19	16	13	20	14	18	16	12	16.7
100	27	19	30	28	36	25	17	25	27	25	47	18	11	25.8
123	23	27	34	37	37	17	21	21	21	27	73	18	57	31.8
155	21	25	31	35	62	26	23	24	23	29	93	15	13	32.3

Table 2c. Pectoralis
Cold/wet/fatigue Condition (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	15	12	12	36	16	13	16	10	12		12	17	13	15.3
22	13	16	11	48	19	16	16	11	11		15	14	13	16.9
33	14	19	31	24	21	17	13	13	15		12	17	13	17.4
45	17	17	28	15	23	20	14	14	14		12	15	11	16.7
57	15	17	16	44	24	20	13	18	18		13	19	13	19.2
100	37	38	22	26	19	25	18	17	20		13	23	19	23.1
123	30	32	28	28	21	18	18	18	20		17	21	21	22.7
155	32	34	27	46	23	21	23	23	23		20	16	13	25.1

Table 2d. Pectoralis
Cold/wet/exercise Condition (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	13	15	12	17	9	12	13	10	24	17	13	14	13	14.0
22	*	*	*	*	*	*	*	*	*	*	*	*	*	*
33	13	13	12	17	12	13	12	10	16	32	13	12	12	14.4
45	*	*	*	*	*	*	*	*	*	*	*	*	*	*
57	12	11	28	15	13	13	12	13	13	12	14	14	13	14.1
100	17	36	55	27	14	16	13	15	23	11	19	17	15	21.4
123	19	48		25	28	18	11	17	21	12	15	12	14	20.0
155	17	28		28	17	24	12	31	26	14	19	15	29	21.7

Table 2e. Pectoralis
Cold/wet/exercise/fatigue Condition (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	13	*	10	15	18	14	13	11	17	16	13	15	11	13.8
22	*	*	*	*	*	*	*	*	*	*	*	*	*	*
33	14	*	17	14	18	13	14	13	14	15	15	13	9	14.1
45	*	*	*	*	*	*	*	*	*	*	*	*	*	*
57	14		13	15	20	14	13	12	13	16	15	13	9	13.9
100	15	9	57	20	25	17	16	27	56	17	43	22	13	25.9
123	15		25	21	28	16	18	23	29	18	33	14	17	21.4
155	25			23	23	22	13	21	21	20	21	19	14	20.2

Note: Data missing from the 22 and 45 minute times is due to the fact that EMGs were not monitored during exercise periods.

Table 2f. Pectoralis
Warm Condition (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	11	17	12	13	13	12	15	12	14	14	13		12	13.2
22	11	18	12	12	11	10	13	13	19	15	13	15	13	13.5
33	10	16	18	13	10	10	15	11	10	14	14	13	12	12.8
45	11	13	15	12	12	12	14	11	12	13	10	11	12	12.2
57	11	12	11	12	10	10	18	11	14	13	10	13	11	12.0
100	11	16	15	12	15	11	14	11	12	13	12	14	12	12.9
123	12	16	24	14	13	12	16	11	14	14	11	13	12	14.0
155	11	13	22	13		13	15	11	11	15	14	12	12	13.5

Table 3a. Biceps brachii
Cold Condition (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	10	9	15	15	11	10	14	13	10	15	12	14	12.3
22	10	13	9	16	38	11	9	12	11	33	14	15	13	15.7
33	12	14	26	15	17	11	11	13	14	48	14	17	12	17.2
45	12	14	25	20	41	16	11	37	13	11	15	15	13	18.7
57	12	12	11	17	25	28	14	15	11	13	13	16	27	16.5
100	14	20	13	15	33	13	16	12	15	17	15	17	13	16.4
123	14	17	16	20	16	11	12	11	19	19	27	14	10	15.8
155	13	13	13	15	17	11	2	12	13	17	13	13	11	12.5

Table 3b. Biceps brachii
Cold/wet Condition (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	11	24	12	31	17	46	25	10	9	24	27	12	12	20.0
22	10	9	21	33	23	45	12	12	16	13	33	10	10	18.3
33	11	12	19	25	26	14	11	10	24	14	34	12	13	17.3
45	11	12	12	16	28	16	11	13	12	13	27	10	11	14.8
57	11	14	16	19	25	25	11	11	11	13	28	12	12	16.0
100	16	22	38	32	29	15	11	18	19	20	27	13	31	22.4
123	18	15	44	28	39	11	18	12	19	27	54	11	59	27.3
155	24	13	39	30	56	17	17	12	17	54	71	10	16	28.9

Table 3c. Biceps brachii
Cold/wet/fatigue Condition (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	15	28	10	17	10	12	14	9	10	14	11	16	13	13.8
22	12	12	9	22	19	15	14	9	10	15	13	12	13	13.5
33	14	23	17	34	19	20	12	13	11	12	11	16	23	17.3
45	17	16	11	17	29	25	13	12	12	12	13	18	15	16.2
57	20	11	10	23	34	34	12	12	13	14	12	18	16	17.6
100	29	12	9	23	40	73	15	10	15	17	12	16	22	22.5
123	34	12	10	32	44	21	15	9	13	37	12	16		21.3
155	31	24	10	47	34	23	18	12	25	26	19	16		23.8

Table 3d. Biceps brachii
Cold/wet/exercise Condition (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	38	9	12	8	11	11	9	37	31	12	15	12	16.7
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	12	10	10	12	11	11	10	9	11	*	12	14	11	11.1
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	11	55	16	11	12	10	12	17	8	12	13	16	16	16.1
100	12	54	13	17	10	11	16	61	35	12	16	20	13	22.3
123	13	56	13	21	12	10	18	20	64	12	13	18	13	21.8
155	14	14	40	100	12	36	22	40	66	14	17	22	51	34.5

Table 3e. Biceps brachii
Cold/wet/exercise/fatigue Condition (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	10	23	8	13	20	13	11	9	12	17	12	15	11	13.4
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	12	10	9	16	17	17	14	10	14	15	18	13	9	13.4
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	12	11	9	12	25	15	13	11	13	14	28	13	9	14.2
100	11	33	27	11	27	13	22	15	45	16	38	17	10	21.9
123	11	15	32	12	33	12	23	12	16	22	22	12	17	18.4
155	16	25	10	12	16	14	20	14	16	24	13	15	28	17.2

Note: Data missing from the 22 and 45 minute times is due to the fact that EMGs were not monitored during exercise periods.

Table 3f. Biceps brachii
Warm Condition (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	8	15	10	57	10	12	15	12	14	15	12		11	15.9
22	9	13	11	33	9	13	13	13	16	21	11	14	12	14.5
33	9	16	11	11	10	13	14	9	10	13	12	12	11	11.6
45	9	12	10	10	11	14	13	10	11	13	9	11	11	11.1
57	9	12	10	10	9	13	19	10	15	13	9	12	10	11.6
100	9	25	10	12	1	11	12	10	11	12	11	13	12	11.5
123	10	13	13	13	12	12	15	11	14	13	9	12	11	12.2
155	9	11	11	12		13	13	10	15	15	12	11	10	11.8

Table 1a. Triceps brachii
Cold Condition (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	15	14	13	14	18	15	15	17	14	13	16	15	19	15.2
22	14	18	13	15	25	15	13	17	17	22	16	16	18	16.8
33	16	23	18	15	19	15	16	15	17	22	14	20	17	17.5
45	16	19	16	16	31	13	15	14	18	15	15	18	18	17.2
57	15	13	16	16	21	19	15	15	17	18	15	20	31	17.8
100	20	31	23	15	19	16	20	18	18	19	20	18	21	19.8
123	19	27	23	21	20	14	17	18	19	22	17	17	15	19.2
155	19	19	15	21	21	16	3	15	20	20	17	17	18	17.0

Table 1b. Triceps brachii
Cold/wet Condition (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	23	14	19	16	18	19	15		14	23	16	17	17	17.6
22	26	11	15	16	23	21	17		19	21	16	14	14	17.8
33	20	14	19	18	23	21	15		20	28	18	17	17	19.2
45	22	14	18	16	24	20	14		17	21	17	14	15	17.7
57	25	15	27	15	25	18	14		14	21	15	16	16	18.4
100	28	14	26	27	21	25	16		22	24	23	18	14	21.5
123	30	24	36	21	21	21	32		17	28	93	16	15	29.5
155	32	10	24	17	30	30	18		17	26	34	14	15	22.3

Table 1c. Triceps brachii
Cold/wet/fatigue Condition (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	18	16	14	13	35	14	27	12	16	47	15	22	19	20.6
22	16	12	12	11	42	15	33	15	15	13	18	17	20	18.4
33	19	19	16	11	34	15	25	17	16	21	15	23	21	19.4
45	18	13	19	12	31	16	27	18	17	21	16	19	18	18.8
57	17	15	15	12	36	15	26	18	18	21	16	24	23	19.7
100	50	22	20	20	30	20	45	13	19	24	17	22	27	25.3
123	26	17	17	24	36	20	34	13	18	67	15	23	22	25.5
155	45	21	17	15	94	19	51	34	27	27	19	27	25	32.4

Table 1d. Triceps brachii
Cold/wet/exercise Condition (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	17	18	14	16	11	17	16	12	30	17	16	19	16	16.8
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	16	14	14	17	17	19	15	13	29	14	16	16	15	16.5
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	16	12	14	12	17	17	17	16	21	17	18	20	15	16.3
100	19	17	16	19	17	15	19	18	24	35	22	17	18	19.7
123	20	22	19	23	21	17	17	18	22	20	17	16	18	19.2
155	19	20	15	19	22	18	20	26	20	25	20	18	24	20.5

Table 1e. Triceps brachii
Cold/wet/exercise/fatigue Condition (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	15	14	13	17	17	18	17	16	17	21	17	21	18	17.0
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	16	13	12	16	15	18	18	17	19	21	18	18	12	16.4
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	17	15	12	19	17	17	16	18	18	20	18	18	18	17.2
100	15	19	15	28	18	17	18	21	66	22	25	24	16	23.4
123	16	22	16	26	21	16	17	14	23	22	28	17	21	19.9
155	31	20	14	18	17	38	17	17	21	20	21	20	17	20.8

Note: Data missing from the 22 and 45 minute times is due to the fact that EMGs were not monitored during exercise periods.

Table 1f. Triceps brachii
Warm Condition (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	11	14	16	16	16	19	15	18	19	16		16	15.7
22	13	16	15	16	15	14	16	16	17	19	16	20	16	16.1
33	12	14	15	16	16	15	18	13	13	19	17	17	15	15.4
45	13	12	13	14	20	18	16	14	16	19	12	14	15	15.1
57	13	15	13	13	16	17	20	14	19	17	12	16	14	15.3
100	12	15	14	15	17	16	15	13	16	17	15	18	16	15.3
123	14	17	15	17	18	17	19	15	19	19	13	22	12	16.7
155	13	16	16	15		23	17	35	15	22	17	17	14	18.3

Table 5a. Rectus femoris
Cold Condition (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	11	9	11	19	12	15	13	10	11	27	12	16	13.7
22	11	15	10	12	20	21	15	13	15	19	15	13	14	14.8
33	12	20	12	12	20	19	13	13	18	23	30	18	13	17.2
45	13	15	12	12	27	24	21	11	20	11	46	16	14	18.6
57	12	17	12	12	28	26	15	13	18	14	35	16	21	18.4
100	15	33	22	12	27	23	22	13	18	15	52	15	30	22.8
123	14	30	24	18	31	28	15	24	15	18	46	17	11	22.4
155	13	18	12	16	30	23	3	30	13	19	37	13	15	18.6

Table 5b. Rectus femoris
Cold/wet Condition (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	16	11	12	12	19	15	14	10	18	15	13	13	19	14.4
22	16	9	9	12	23	15	16	14	16	14	23	12	15	14.9
33	13	12	10	20	23	15	16	13	21	14	17	15	27	16.6
45	13	15	11	12	21	16	14	10	20	13	24	13	23	15.8
57	17	21	16	12	20	15	12	11	23	14	31	14	32	18.3
100	32	13	23	14	26	24	13	15	20	16	48	15	34	22.5
123	31	14	27	13	22	19	45	16	23	24	97	13	27	28.5
155	20	17	19	14	24	27	15	19	18	27	89	15	22	25.1

Table 5c. Rectus femoris
Cold/wet/fatigue Condition (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	15	12	21	14	11	11	24	9	11	17	12	16	14	14.4
22	14	15	18	10	14	12	26	10	10	23	17	12	16	15.2
33	14	19	21	19	21	12	21	12	14	20	32	17	35	19.8
45	14	13	17	10	21	14	24	12	14	16	24	14	37	17.7
57	14	12	11	11	21	13	23	14	18	16	27	23	20	17.2
100	18	21	11	12	12	16	40	15	18	18	47	17	26	20.8
123	17	16	13	14	23	14	28	18	16	23	44	17	57	23.1
155	20	20	17	12	60	13	44	18	39	21	36	16	15	25.5

Table 5d. Rectus femoris
Cold/wet/exercise Condition (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	13	11	10	13	11	12	12	9	18	13	14	15	14	12.7
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	13	11	11	13	15	12	11	10	13	12	14	13	13	12.4
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	12	10	11	10	13	11	13	13	10	13	13	15	13	12.1
100	13	29	10	12	15	12	17	15	22	16	44	19	29	19.5
123	14	36	11	15	23	12	17	18	18	15	40	22	16	19.8
155	14	27	12	16	21	17	16	33	20	16	36	16	31	21.2

Table 5e. Rectus femoris
Cold/wet/exercise/fatigue Condition (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	11	14	9	18	17	14	12	12	12	16	15	26	11	14.4
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	12	12	11	28	17	13	13	13	15	15	16	14	9	14.5
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	12	12	12	25	14	13	12	14	14	14	16	14	10	14.0
100	11	29	25	28	14	14	22	21	32	17	53	30	11	23.6
123	11	32	28	24	17	13	34	20	17	21	24	22	14	21.3
155	12	23	12	25	11	13	34	22	19	17	19	29	27	20.2

Note: Data missing from the 22 and 45 minute times is due to the fact that EMGs were not monitored during exercise periods.

Table 5f. Rectus femoris
Warm Condition (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	9	9	11	13	11	12	15	11	14	14	13		12	12.0
22	10	12	11	12	9	11	13	14	14	15	12	15	12	12.3
33	9	17	11	16	10	11	14	10	10	14	13	13	11	12.2
45	10	9	10	15	12	14	13	10	12	14	9	11	12	11.6
57	10	11	10	15	10	11	16	10	14	13	9	12	10	11.6
100	9	11	10	20	11	11	12	10	12	13	11	14	12	12.0
123	11	14	11	20	12	12	15	11	14	14	9	12	11	12.8
155	11	14	16	21		12	13	10	11	16	12	11	11	13.2

Table 6a. Biceps femoris
Cold Condition (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	10	9	13	12	11		12	10	10	11	11	14	11.3
22	11	12	9	11	11	17		12	11	21	12	11	13	12.6
33	12	13	15	13	13	12		13	12	22	14	15	13	13.9
45	12	11	12	13	19	10		14	14	11	20	13	13	13.5
57	11	15	16	13	29	20		13	11	14	13	14	27	16.3
100	13	21	11	13	12	12		14	12	14	22	13	15	14.3
123	13	21	15	12	13	10		10	13	18	12	12	10	13.3
155	14	16	14	12	14	12		11	10	15	12	12	11	12.8

Table 6b. Biceps femoris
Cold/wet Condition (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	10	12	12	13	18	18	13	23	9	18	14	12	14	14.3
22	11	9	9	13	21	19	13	28	14	15	18	11	11	14.8
33	11	11	12	17	21	23	14	27	13	16	20	13	17	16.5
45	11	10	11	12	20	23	12	27	12	20	15	10	12	15.0
57	12	12	27	12	16	19	12	27	10	13	13	12	25	16.2
100	13	12	12	14	23	30	15	27	12	16	64	13	22	21.0
123	13	17	18	13	19	23	17	32	13	15	87	12	13	22.5
155	11	15	10	13	22	32	16	29	11	15	126	10	13	24.8

Table 6c. Biceps femoris
Cold/wet/fatigue Condition (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	14	11	9	10	13	11	14	16	10	17	12	16	14	12.8
22	12	8	10	9	17	12	16	26	10	16	13	12	13	13.4
33	14	13	16	9	21	12	12	27	11	14	12	17	12	14.6
45	14	10	15	11	20	13	14	30	12	16	12	14	14	15.0
57	13	11	10	10	19	11	13	33	13	19	12	17	18	15.3
100	14	11	14	15	10	11	24	26	14	20	15	14	20	16.0
123	15	12	16	16	18	14	19	25	12	23	13	15	42	18.5
155	13	13		14	41	13	22	22	18	16	14	16	13	17.9

Table 6d. Biceps femoris
Cold/wet/exercise Condition (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	11	10	12	9	11	11	8	11	14	12	14	12	11.3
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	12	11	12	13	12	10	10	10	13	10	12	12	11	11.4
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	12	9	11	10	13	11	12	10	9	13	14	15	11	11.5
100	11	16	12	15	11	11	18	12	16	15	17	17	21	14.8
123	13	22	28	12	16	11	12	13	12	16	14	13	14	15.1
155	12	14	26	15	14	13	16	15	15	18	15	13	33	16.8

Table 6e. Biceps femoris
Cold/wet/exercise/fatigue Condition (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	10	11	8	13	15	13	12	10	11	15	12	16	16	12.5
22	*	*	*	*	*	*	*	*	*	*	*	*	*	
33	11	9	19	11	14	12	13	11	15	15	14	13	10	12.8
45	*	*	*	*	*	*	*	*	*	*	*	*	*	
57	12	11	39	14	14	13	11	11	14	14	16	13	17	15.3
100	12	13	43	14	13	13	20	21	12	17	21	16	12	17.5
123	12	20	17	13	13	11	16	14	15	18	23	12	19	15.6
155	14	14		13	11	11	14	22	15	15	24	14	24	15.9

Note: Data missing from the 22 and 45 minute times is due to the fact that EMGs were not monitored during exercise periods.

Table 6f. Biceps femoris
Warm Condition (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	9	9	11	13	65	12	14	11	14	13	13		12	16.3
22	10	12	11	13	72	11	12	14	13	13	12	15	12	16.9
33	9	15	11	12	71	10	13	10	10	13	13	12	11	16.2
45	10	9	10	12	67	13	12	10	12	13	9	10	11	15.2
57	10	11	10	10	67	10	16	10	14	12	9	11	10	15.4
100	9	13	11	12	63	11	11	10	12	12	12	13	12	15.5
123	11	12	11	14	50	12	14	11	14	13	9	12	11	14.9
155	11	12	12	11		12	13	10	11	15	12	11	10	11.7

Table 7a. Soleus
Cold Condition (Condition 1)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	9	36	10	15	12	13	15		12	11	11	15	14.3
22	10	17	36	10	16	13	12	12		20	11	11	15	15.3
33	12	20	34	11	13	12	12	15		31	12	14	13	16.6
45	12	23	35	11	42	12	12	10		13	14	13	14	17.6
57	11	59	37	11	55	15	11	13		30	11	14	18	23.8
100	12	38	10	10	14	12	10	12		14	14	13	37	16.3
123	12	53	27	13	12	10	11	11		20	13	12	11	17.1
155	12	27	21	12	14	13	8	10		15	11	13	14	14.2

Table 7b. Soleus
Cold/wet Condition (Condition 2)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	9	12	12	14	14	15	11	11	9	26	12	18	12	13.5
22	10	10	8	17	15	17	12	15	18	14	36	13	10	15.0
33	11	10	10	47	16	21	11	15	13	16	51	15	12	19.1
45	11	41	10	12	15	20	11	15	12	14	39	13	11	17.2
57	12	12	13	14	13	16	10	14	13	17	45	1	12	14.8
100	10	14	11	13	16	21	10	19	18	18	80	14	8	19.4
123	12	15	14	14	13	19	12	21	15	19	150	12	11	25.2
155	10	13	12	13	20	27	12	21	12	21	120	11	10	23.2

Table 7c. Soleus
Cold/wet/fatigue Condition (Condition 3)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	13	11	10	13	12	11	13	11	46	14	15	15	13	15.2
22	12	9	14	12	8	12	13	19	51	15	17	12	12	15.8
33	13	14	19	17	9	13	10	21	62	16	15	16	11	18.2
45	14	14	14	11	20	15	12	27	64	15	15	13	13	19.0
57	16	16	10	11	30	14	11	27	81	24	14	16	14	21.8
100	14	10	10	22	16	12	14	40	92	16	40	21	15	24.8
123	14	11	11	11	13	15	15	36	12	25	25	15	22	17.3
155	14	14	11	12	42	16	20	15	43	16	32	16	11	20.2

Table 7d. Soleus
Cold/wet/exercise Condition (Condition 4)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	12	10	9	12	8	11	11	8		19	18	14	11	11.9
22	*	*	*	*	*	*	*	*		*	*	*	*	
33	12	10	11	12	11	11	10	10		14	18	12	10	11.8
45	*	*	*	*	*	*	*	*		*	*	*	*	
57	12	8	10	9	12	15	12	13		13	25	14	10	12.8
100	14	13	10	10	17	11	12	14		13	37	12	21	15.3
123	26	14	13	11	14	10	11	18		13	31	11	13	15.4
155	13	11	15	13	13	11	11	28		15	26	12	13	15.1

Table 7e. Soleus
Cold/wet/exercise/fatigue Condition (Condition 5)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	10	12	8	20	12	13	12	9	11	22	12		13	12.8
22	*	*	*	*	*	*	*	*	*	*	*		*	
33	11	10	32	11	11	15	13	10	14	22	22		10	15.1
45	*	*	*	*	*	*	*	*	*	*	*		*	
57	12	11	22	12	13	16	12	11	13	22	15		11	14.2
100	10	18	39	21	12	13	14	30	11	27	38		9	20.2
123	11	21	10	13	13	11	20	18	14	65	31		21	20.7
155	11	12	17	13	11	18	19	12	14	53	61		14	21.3

Note: Data missing from the 22 and 45 minute times is due to the fact that EMGs were not monitored during exercise periods.

Table 7f. Soleus
Warm Condition (Condition 6)

Minutes	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
12	9	9	11	13	10	10	13	1	13	13	12		11	10.4
22	10	12	11	12	9	9	12	12	12	13	11	14	12	11.5
33	9	36	11	12	10	9	13	10	10	13	12	14	11	13.1
45	10	10	10	12	10	12	12	10	12	13	9	12	11	11.0
57	10	11	10	11	9	9	15	10	13	12	9	11	10	10.8
100	10	12	11	12	11	11	10	9	11	14	11	13	11	11.2
123	11	13	12	13	12	12	14	11	14	13	9	12	11	12.1
155	13	15	14	16		12	13	10	11	15	11	11	10	12.6

Phase II

CONTRACT NO.:	N00014-88-K-0582
TITLE:	Studies of Neural and Cognitive Function in Subjects Exposed to the Marine-Air Interface
SUBTITLE:	Phase II: Characterization of Central and Peripheral Nervous System Function During Central versus Peripheral Body Cooling.
PRINCIPAL INVESTIGATORS:	Lorentz E. Wittmers, Jr., M.D., Ph. D., Richard G. Hoffman, PhD.
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REPORT DATE:	10/26/93
TYPE OF REPORT:	Final Technical Report
PREPARED FOR:	Naval Medical Research and Development Command
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Introduction

Exposure to cold has several debilitating effects. These include loss of manual dexterity due to peripheral cooling of the hands and feet, and reduction of cognitive abilities, especially for more complex tasks (4). The effect of cold on cognitive function depends upon the length and difficulty of the task involved. Ellis, (2) and Teichner (11) reported that response times during simple and serial choice reaction time tasks are unchanged when subjects are exposed to cold air. Ellis (3) and Enander (4) found faster responses to more complex reaction time tasks involving either a brief delay or multiple choice. However, the number of mistakes made by subjects during the more complex tasks was significantly increased during cold exposure.

Two hypotheses for the performance changes resulting from cold exposure have been proposed (5). The first suggests that discomfort from cold exposure distracts subjects from focusing their attention on a given task. This results in slower response times and an increased occurrence of errors (2, 11, 14). The second suggests that cold induced performance decrements are the result of increased arousal levels which impair attention (4). Ellis (2) suggested the first hypothesis because decrements in performance can be observed early during a given exposure, and performance does not continue to decline thereafter. Enander (4), however, concluded that faster response times observed in the cold were better explained by the arousal hypothesis since the distraction hypothesis does not predict cold related increases in reaction time performance.

Few reports have related the cognitive effects of cold exposure to measured physiological changes in nervous system function. It is well established that deep hypothermia induced under anesthesia causes an increase in the latency of evoked potentials (EPs) in humans (Markland 1984), but the effects of mild to moderate hypothermia on nervous system function in unanesthetized humans are not well understood.

Several studies have attempted to measure the physiological changes that accompany cold exposure, including changes in central and peripheral nerve conduction. Fitzgibbon, et. al (6) reported that 3-4°C core cooling by immersion in cold water resulted in 10-20% increases in the latency of peaks in visual evoked potentials (VEPs) in some subjects, but this result was not statistically significant when group data was analyzed. They concluded that moderate hypothermia with core temperature approaching 33.5°C is on the borderline for inducing significant alteration of brain electrical activity in unanesthetized subjects. Marshall and Donchin (9), however, reported a significant correlation between auditory evoked potential (AEP) latencies and decreases of 1-2°C resulting from circadian rhythm temperature variations. Van Orden, et. al (13) reported that a 50 minute exposure to cold air (4°C), which caused no significant core temperature change, resulted in EPs with consistently shorter latencies than

those recorded during exposure to 22°C air. They suggested that faster central nervous system (CNS) processing of sensory stimuli (arousal) takes place during cold exposure.

The decreases in reaction times reported in the preceding discussion would appear to be inconsistent with the known physiological effects of cooling on central and peripheral nerve conduction, namely slowing of nerve conduction. If mild to moderate cold exposure does cause a decrease in reaction time via an arousal mechanism, the increase in reaction times recorded in studies employing substantial cooling may have been affected by the slowing of nerve conduction. This would offset increased arousal, thus blunting the decreases in response times that arousal alone would have caused (13). Therefore, Van Orden et al. (13) suggested that a moderate level of cooling may increase CNS arousal levels significantly, yet leave peripheral motor function unaffected, thus permitting arousal increases to be measured behaviorally via response latencies. Conversely, if core cooling could be achieved without increasing arousal level, decreases in response latencies would be observed due to the slowing of nerve conduction velocities.

In order to test these hypotheses, peripheral and central methods of cooling were applied to evaluate their effects on simple reaction time and auditory, visual, and somatosensory evoked potentials.

Methods

Eleven male subjects, age 25.0 ± 3.0, were informed as to the general purpose, procedure, and possible risks of the experiments, and gave their written consent prior to participation. All subjects were screened for cardiovascular abnormalities, physical fitness, and body fat content as in Phase 1 of this study. Protocols for this project were approved jointly by the University of Minnesota Committee for the use of Human Subjects in Research, and the United States Navy prior to subject recruitment. Subject anthropomorphic data is listed in Appendix I.

General Procedures:

Reaction times, Auditory Evoked Potentials (AEPs), Visual Evoked Potentials (VEPs), and Somatosensory Evoked Potentials (SEPs) were sampled with subjects in a semi-supine position in an environmental chamber during cold air (7°C), and internal cooling (27°C, ice slurry ingestion) conditions. Subjects reported to the laboratory within one hour of the same time of day for each experiment to minimize circadian temperature variations. Upon arrival they were instrumented with rectal, tympanic, and skin thermocouples (see Figure 1) and bipolar surface electrodes (see Figures 3,4,5) for EPs and dressed in a military type uniform consisting of cotton underwear and socks, cotton/polyester long sleeved shirts, and cotton long pants. Subjects were then seated in the environmental chamber and baseline reaction times, EPs and temperatures were recorded at an ambient temperature of 27°C.

For the 7°C condition, the air temperature was gradually decreased from 27°C to 7°C over 30 minutes and remained at 7°±1° C for the remainder of the experiment. EPs were sampled 10 minutes after the chamber temperature reached 7°C (approximately 40 minutes after chamber temperature began to decline) and again when a drop of several tenths of a degree in rectal temperature from the control value was observed (control and 80 minute temperatures were 37.5 ± 0.1 and 37.2 ± 0.2 [mean ± sem]). This sample occurred approximately 80 minutes after chamber temperature began to decline, although this time varied considerably between subjects). The original intent was to continue cooling until core temperatures were similar to those in the ice slurry condition, however, in the cold air condition temperatures did not continue to drop due to subjects' thermoregulatory reflexes (shivering, vasoconstriction).

For the ice slurry ingestion condition, control measurements were recorded as above. To induce core cooling subjects ingested approximately 2 liters of flavored ice slurry over 80 minutes while remaining semi-supine in the environmental chamber at 27°C. EPs were recorded approximately 40 and 80 minutes after ice slurry ingestion began. Experiments were counter-balanced to minimize order effects. No subject performed two experiments within the same week.

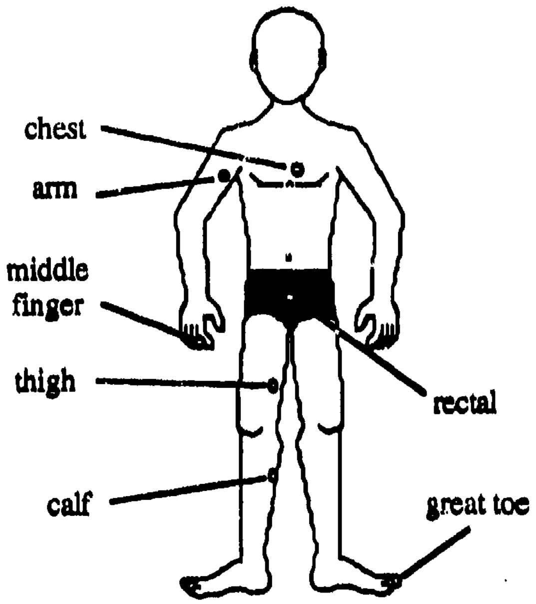

Figure 1. Placement of temperature sensors.

Instrumentation:

Rectal temperature (T_R) was monitored with a disposable rectal thermocouple (Type T, Physitemp, Inc., Clifton, NJ) inserted approximately 8 cm. beyond the anus. Tympanic temperature was monitored using a cotton tipped thermocouple placed against the tympanic membrane (Monotherm Inc. St Louis, Mo.). Skin temperatures were monitored using copper-constantan skin thermocouples (#SST-1. Sensortek, Inc., Clifton, NJ) on the medial calf, medial thigh, lateral upper arm, and chest, 2nd finger, and big toe (see Figure 1).

Mean skin temperature (T_{MS}) was calculated employing the approach of Ramanathan (10) as presented in equation 1.

$$T_{MS} = 0.3(\text{chest} + \text{arm}) + 0.2(\text{calf} + \text{thigh}) \qquad (1)$$

Temperatures were sampled 6 times per minute and one minute averages were recorded to the nearest 0.1°C using a computerized data acquisition system (Macintosh SE microcomputer, A/D board and Analog Connection Workbench data acquisition software from Strawberry Tree Inc., Sunnyvale, CA). A bipolar modified lead-5 ECG was monitored by telemetry (Transkinetics Inc. Canton, MA) throughout cold exposure to evaluate cardiac status, determine heart rate, and insure subject safety.

Visual analog scales were used to measure subjects' perceptions of their peripheral (finger and toe) and overall temperatures and thermal comfort levels. Examples of this scale are presented in Figure 2. More detailed discussion of this method is given in the Phase I report.

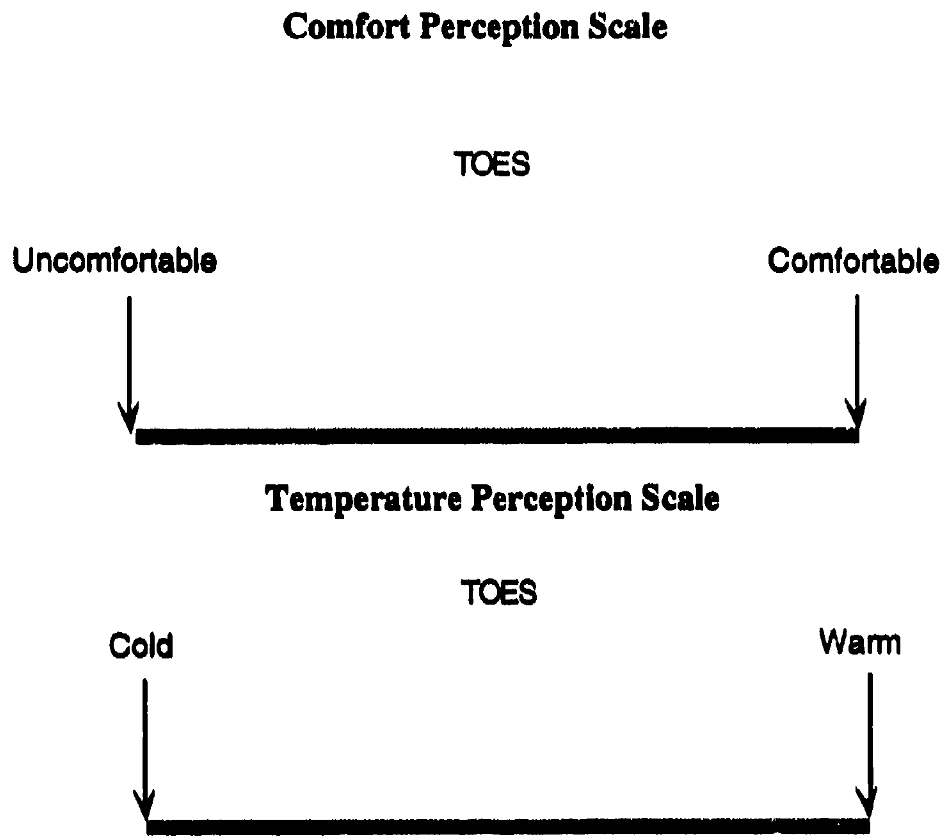

Figure 2. Example of the visual analog scales used to measure comfort and temperature perceptions. A separate scale was used for each rating and for fingers, toes, and body.

Simple reaction time was measured using a personal computer and reaction time software (software: copyright Martin Wiene, 02-21-89). Subjects were familiarized with the program which required them to depress a key when an indicator appeared on the computer screen. Reaction time was measured immediately before EP measurements. Ten reaction times were recorded and averaged for each sample time (control, 40, and 80 minutes).

A Nicolet Viking™ (Nicolet Biomedical Inc., Madison, WI) was used to sample, average, and store evoked potential waveforms as well as produce the necessary stimuli (see Figures 3,4,5 for equipment setups and the following electrode placements).

AEPs were recorded from C_z referenced to A_2, with F_{pz} serving as the ground (Figure 3). Condensation stimuli at 75dB were presented to the subjects left ear at a rate of 11.1 Hz. Waveforms were amplified and filtered (bandwidth 0.1-3.0 Khz). Two sets of 2000 sweeps were averaged and superimposed for measurement of peak latencies.

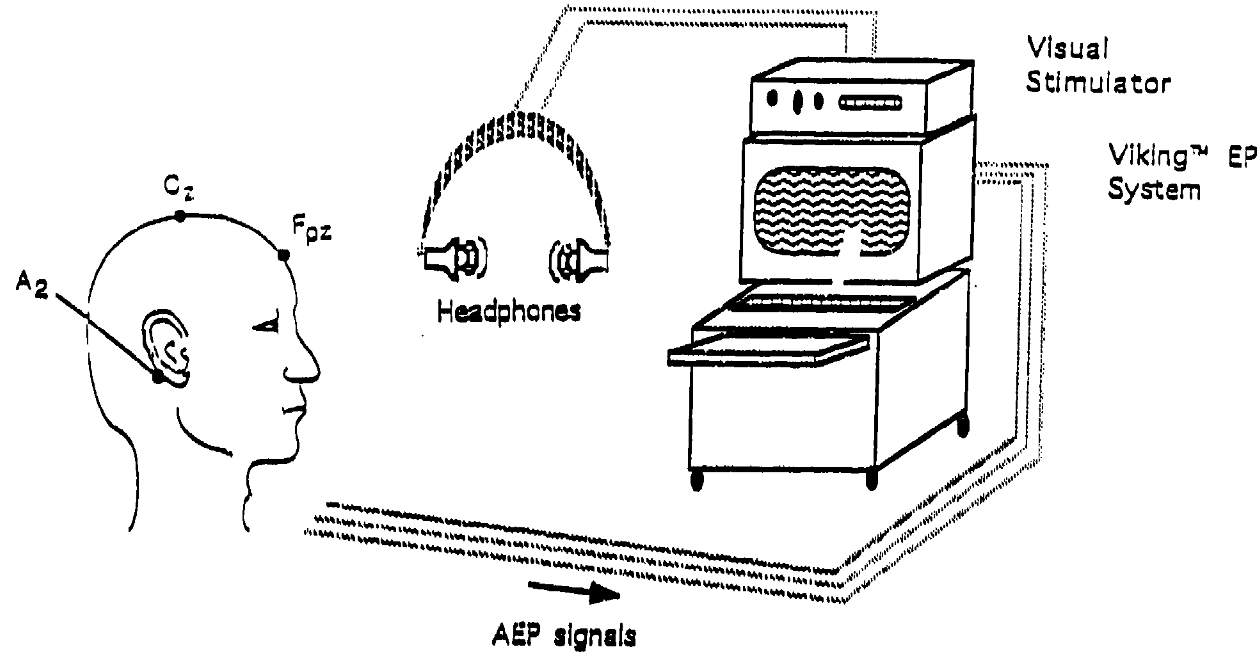

Figure 3. Configuration of equipment and electrode placement for measurement of AEPs.

The visual stimulus for VEPs was provided by a Nicolet 1015 Visual stimulator and monitor set for a 16 x 12 checkerboard grid. Visual stimuli were located 1 meter from the subject and were phase reversed at the rate of 1.1 per second. The recording epoch for the VEP was 1 second and the high and low filter settings were 50 and 0.5 Hz respectively. VEPs were recorded from O, referenced to F_{pz}, and A_2 served as the ground (Figure 4). One hundred sweeps were averaged and 2 consecutive averages were superimposed for peak measurement.

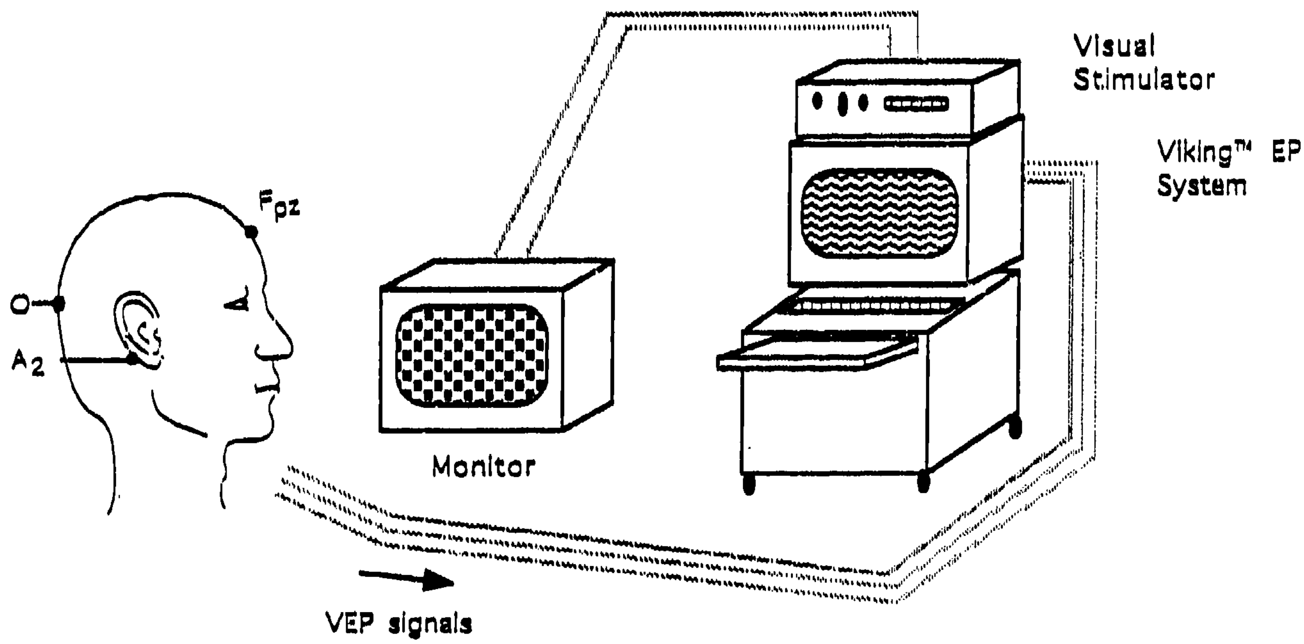

Figure 4. Configuration of equipment and placement of electrodes for VEPs

Somatosensory evoked potentials (SEPs) were recorded from three locations: scalp, 12th thoracic vertebra, and the popliteal fossa (Figure 5). A 0.2ms supramaximal stimulus at the rate of 2.3 Hz was applied at the ankle behind the medial malleolus. For scalp recordings the active electrode was placed at C_Z' and referenced to F_{PZ}'. For the 12th thoracic vertebra recording (T12) the active electrode was placed over the T12 spinous process. For the popliteal fossa recording (PF) the active electrode was placed over the tibial nerve approximately 2cm above the popliteal fossa. High frequency and low frequency filter settings were 2 Hz and 2000 KHz respectively. Three to four hundred sweeps were averaged and two averages were superimposed for peak measurement.

Muscle artifacts due to shivering were suppressed by application of radiant heat from a heat lamp to the subjects face and body, and by having the subjects don heated gloves only during EP recording. This inhibited shivering in most of the subjects for a sufficient time to collect EP data. SEPs are particularly sensitive to muscle activity and presented the most difficulty in data collection under cold conditions when shivering was prominent.

Repeated measures analysis of variance with Tukey post hoc comparisons and paired Students t-tests were used to analyze for significant effects of condition on evoked potential latencies.

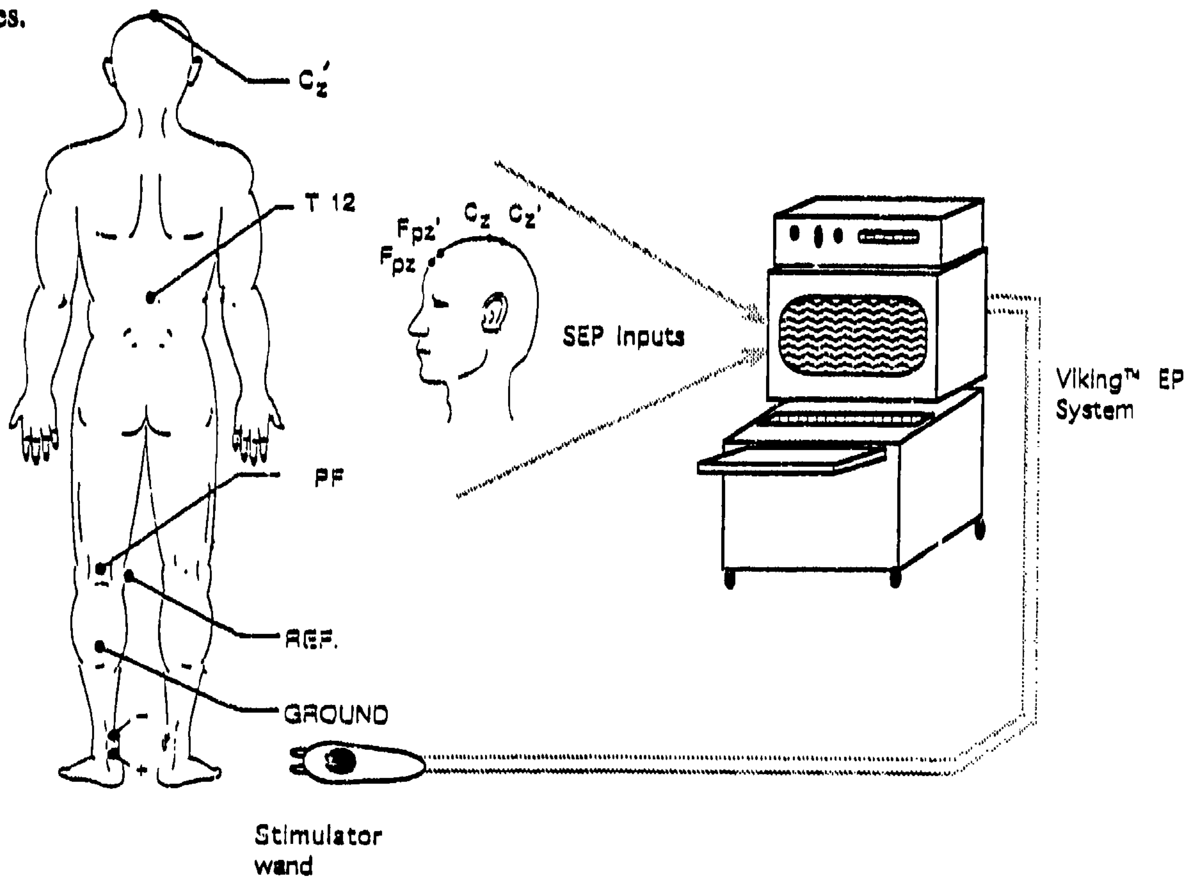

Figure 5. Configuration of equipment and placement of electrodes for SEPs.

Results

Rectal, tympanic, and mean skin temperatures decreased significantly from control ($p \leq 0.05$) in most cases under both conditions by 40 and 80 minutes, when evoked potentials were sampled (Figures 6a-c). Temperature data for individual subjects is presented in Appendix II.

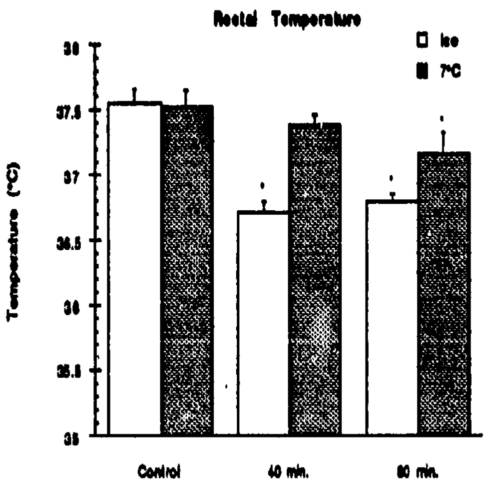

Figure 6. a. Rectal temperature as a function of time and condition.

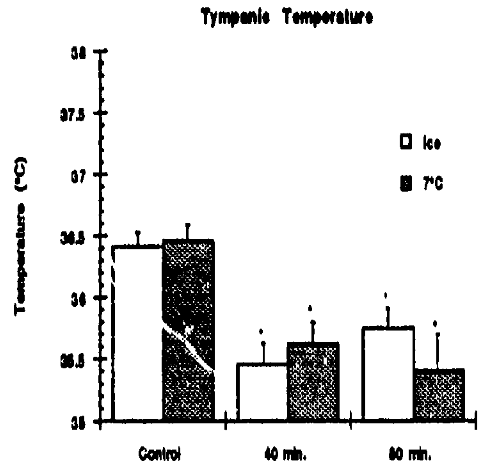

Figure 6. b. Tympanic temperature as a function of time and condition.

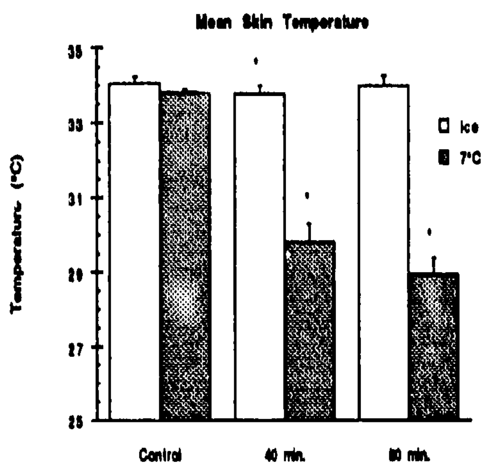

Figure 6. c. Mean skin temperature as a function of time and condition.

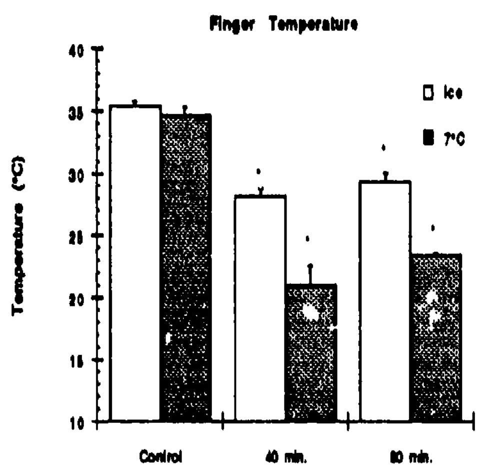

Figure 6. d. Finger temperature as a function of time and condition.

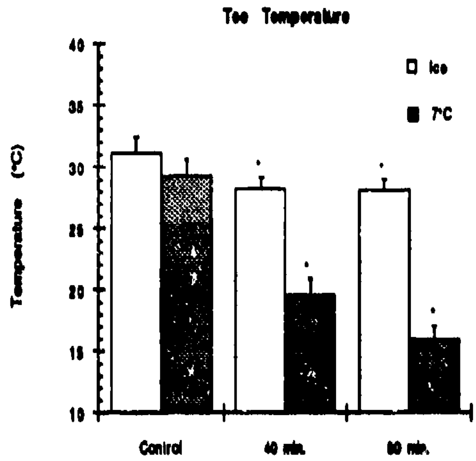

Figure 6. e. Toe temperature as a function of time and condition.

The exceptions were the first rectal temperature during exposure to 7°C air, and mean skin temperature at the late ice slurry sample. These exceptions illustrate the different effects of each condition, e.g. the 7°C air condition resulted in greater peripheral cooling and thus lower skin temperatures, while the ice slurry ingestion resulted in a rapid decrease in core temperature with little decrease in skin temperature.

Finger and toe temperatures (Figures 6d-e) decreased in both conditions, but to a greater extent in the 7°C air exposure.

Temperature and comfort perceptions followed similar patterns (Figure 7a-f). Finger and toe temperature and comfort perceptions decreased only slightly during ice slurry ingestion but significantly more during cold air exposure ($p \leq 0.05$). Temperature and comfort perceptions for the rest of the body decreased slightly more during cold air exposure than during ice ingestion, even though core temperature did not decrease as much. In fact, core temperature increased between the early and late 7°C exposure measurements, but body comfort and temperature perceptions showed an decreasing trend. Perception data for individual subjects is presented in Appendix III.

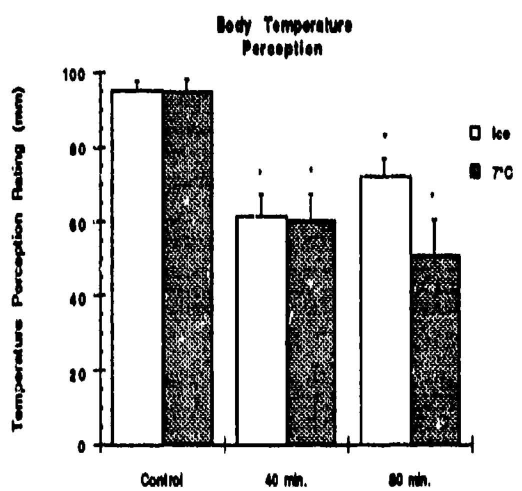

Figure 7. a. Body temperature perception as a function of time and condition.

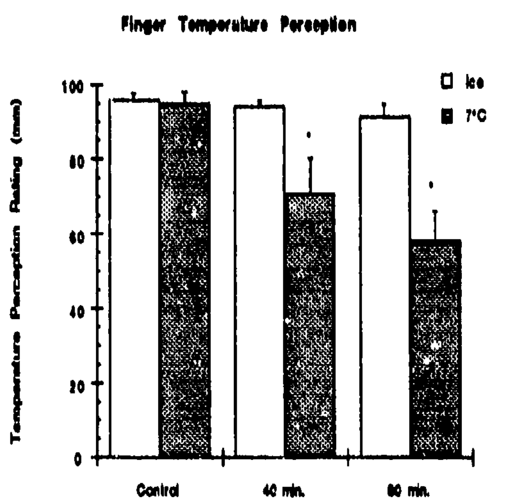

Figure 7. b. Finger temperature perception as a function of time and condition.

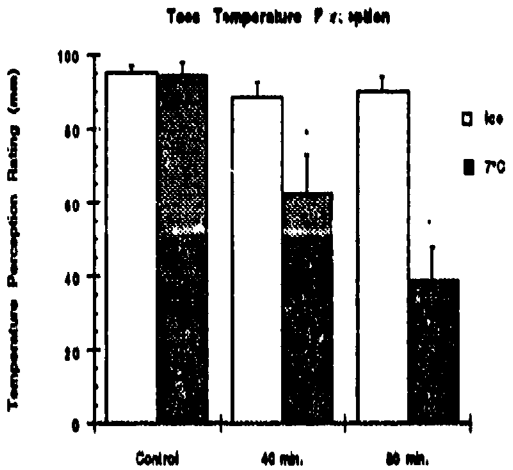

Figure 7. c. Toe temperature perception as a function of time and condition.

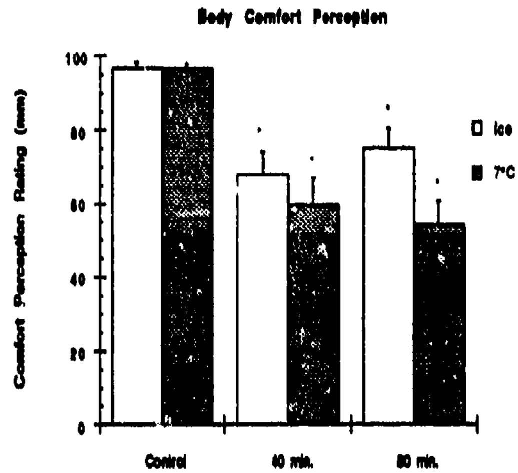

Figure 7. d. Body comfort perception as a function of time and condition.

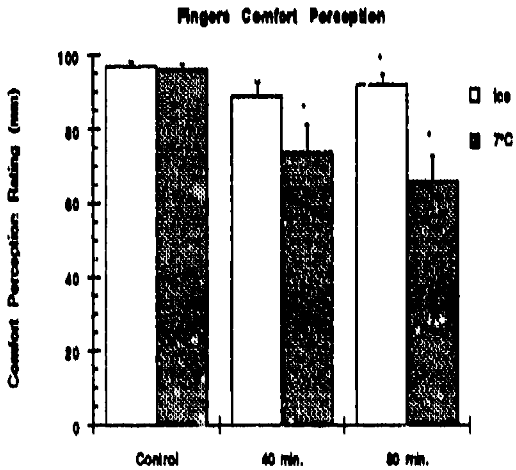

Figure 7. e. Finger comfort perception as a function of time and condition.

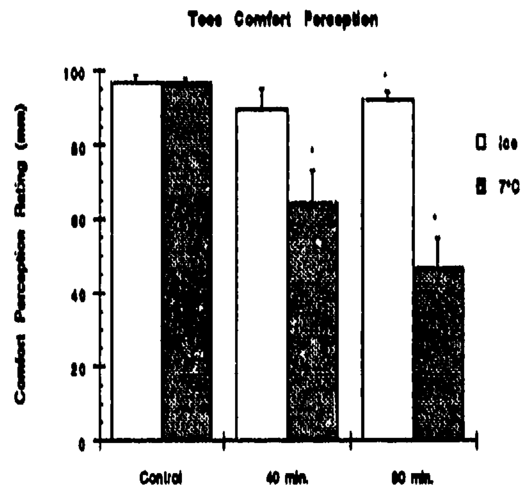

Figure 7. f. Toe comfort perception as a function of time and condition.

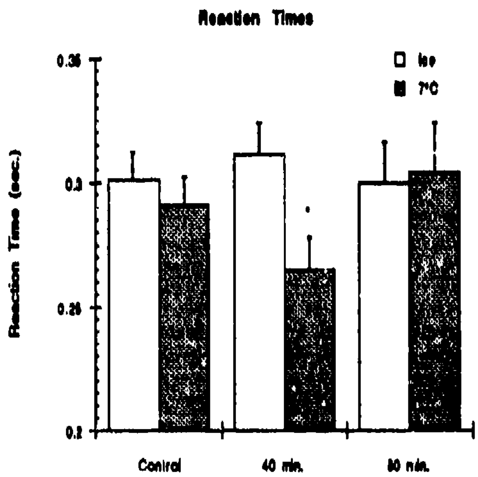

Figure 8. Simple reaction time (average of 10 samples) as a function of time and condition.

Reaction time decreased significantly only during the first 7°C sample when rectal temperature was unchanged. Other reaction times did not change (Figure 8). Reaction time data is presented in Appendix IV.

A number of evoked potentials showed significant changes in latency. Significant and marginally significant changes in latencies and p values are listed in Table 1. Increased latencies in AEPs occurred only after ice slurry ingestion, probably resulting from the effects of cooling on central nervous system

Table 1. Evoked Potential Latencies and p values.

Test and Variable	Significant Comparisons	Mean EP Latency (msec.)	SEM	p
AEP				
V	Control	5.89	0.07	
	Ice 80	6.05	0.04	0.006
I-III	Control	4.08	0.07	
	Ice 40	4.35	0.12	0.013
I-V	Control	4.08	0.07	
	Ice 40	4.35	0.12	0.013
	Control	4.08	0.07	
	Ice 80	4.29	0.13	0.069
III-V	Control	1.91	0.04	
	Ice 40	2.11	0.09	0.020
	Control	1.91	0.04	
	Ice 80	2.06	0.08	0.072
VEP				
N75	Control	72.11	1.85	
	Ice 40	75.67	1.44	0.098
	Ice 40	76.67	1.56	
	Ice 80	72.56	1.29	0.014
	Ice 40	77.57	1.66	
	7°C 80	72.43	1.69	0.067
P100	Ice 40	103.89	1.96	
	Ice 80	100.56	1.14	0.053
	Ice 40	104.78	1.70	
	7°C 40	98.78	1.61	0.006
	Ice 40	102.88	1.38	
	7°C 80	99.38	1.55	0.008
	Control	103.78	1.68	
	7°C 40	98.78	1.61	0.004

Table 1 (cont.) Evoked Potential Latencies and p values.

Test and Variable	Significant Comparisons	Mean EP Latency (msec)	SEM	p
VEP				
N145	Ice 40	142.86	6.40	
	Ice 80	136.00	5.35	0.027
	Ice 40	144.14	6.47	
	7 C 40	133.14	6.50	0.029
	Control	131.88	2.32	
	7 C 80	126.88	2.00	0.093
SEP				
P37	Ice 40	37.45	1.82	
	Ice 80	36.75	1.63	0.067
	Control	35.20	1.24	
	7 C 80	38.14	1.25	0.008
	7 C 40	36.30	1.23	
	7 C 80	38.36	1.39	0.002
N45	Control	44.40	1.25	
	7 C 80	46.18	1.37	0.001
	7 C 40	44.91	1.32	
	7 C 80	46.33	1.53	0.008
N21	Control	21.07	0.18	
	7 C 80	23.00	0.60	0.048
Pf	Control	8.58	0.48	
	Ice 40	9.40	0.59	0.067
	Control	8.18	0.47	
	7 C 40	9.20	0.46	0.006
	Control	7.89	0.34	
	7 C 80	9.43	0.42	0.000
	7 C 40	8.66	0.33	
	7 C 80	9.43	0.42	0.003

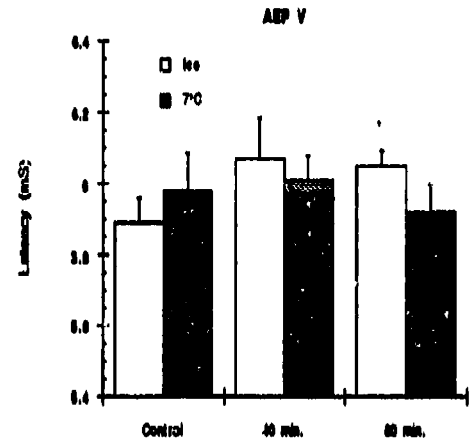

Figure 9. Auditory evoked potential latencies of Peak V as a function of time and condition.

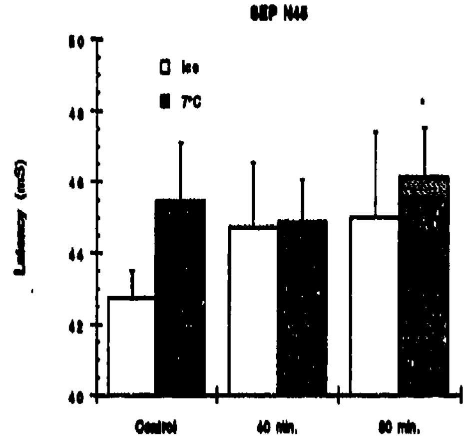

Figure 10. Somatosensory evoked potential latencies of Peak N45 as a function of time and condition.

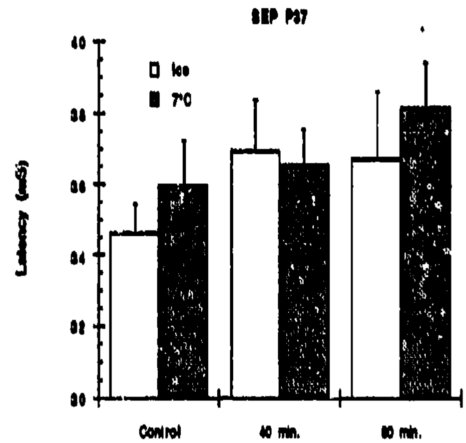

Figure 11. Somatosensory evoked potential latencies of Peak P37 as a function of time and condition.

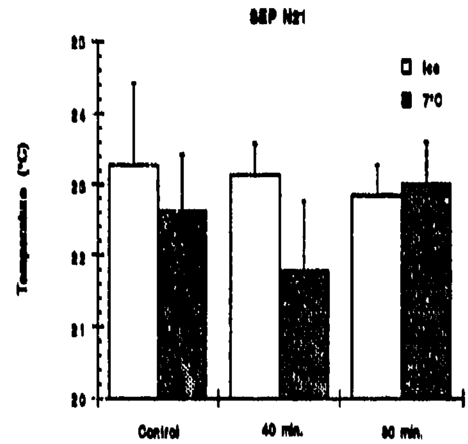

Figure 12. Somatosensory evoked potential latencies of Peak N21 as a function of time and condition.

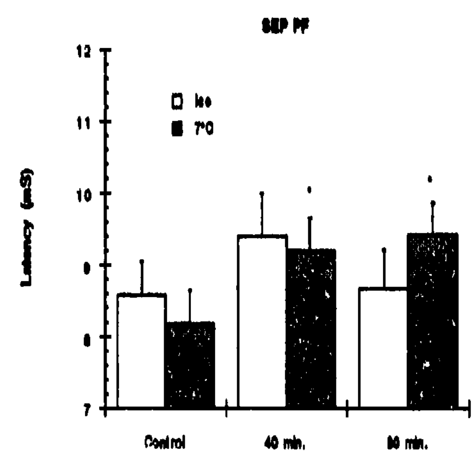

Figure 13. Somatosensory evoked potential latencies of Peak P37 as a function of time and condition.

conduction (Figure 9). In contrast, 7°C air exposure caused increases in latencies of SEPs only, demonstrating the effect of peripheral cooling on peripheral conduction (Figures 10-13).

The most consistent of VEP peaks is typically P100. Unlike the SEPs, the P100 VEP peak showed a significant decrease in latency from control after 40 minutes of cold exposure (Figure 14). In contrast, the occurrence of P100 was significantly later in the ice slurry condition (when rectal temperatures were lower) than in

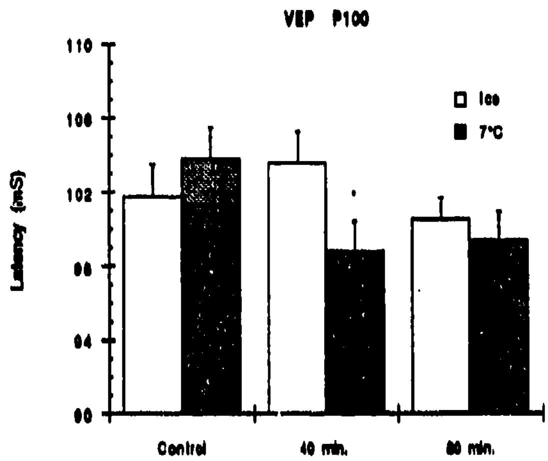

Figure 14. Visual evoked potential latencies of peak P100 as a function of time and condition.

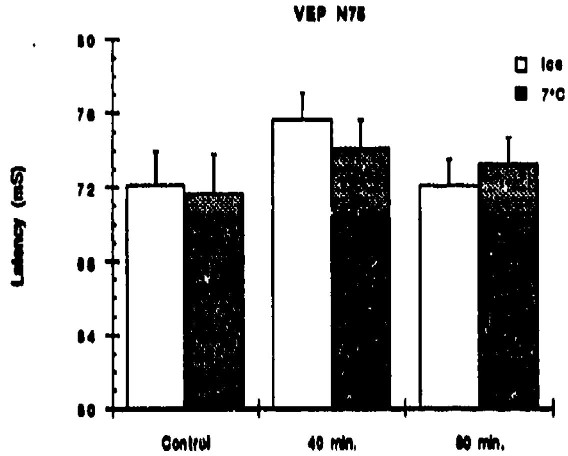

Figure 15. Visual evoked potential latencies of peak P100 as a function of time and condition.

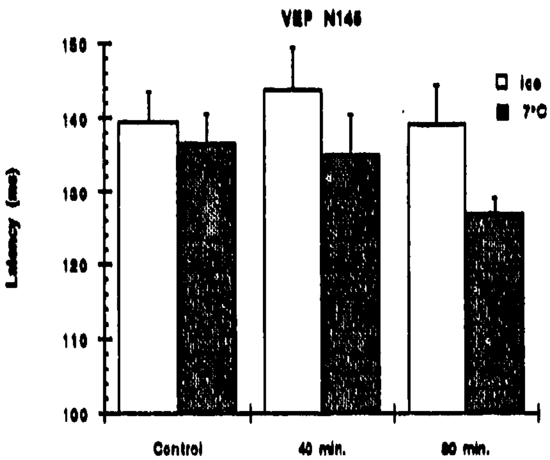

Figure 16. Visual evoked potential latencies of peak N145 as a function of time and condition.

the cold air condition. Similar trends were present in the other VEP peaks monitored (Figures 15 and 16). EP latencies for each individual subject are presented in Appendix V. It is interesting to note that significant increases in latency occurred in AEPs and SEPs, but significant decreases in latency occurred in VEPs. These decreases in VEP latency, however, occurred when rectal temperatures were increasing or remaining steady.

Discussion

These experiments were designed to differentiate between the effects of core cooling and peripheral cooling during cold exposure, on central nervous system conduction and reaction time performance. Substantial reduction of the core temperature reduces nerve conduction velocity (8). This would be expected to slow physical performance, including reaction time. Cold air exposure, however, also causes considerable discomfort. The distraction and arousal which results from cold exposure has been hypothesized to cause both faster reaction times and decreases in accuracy during psychomotor performance (3, 4).

In these experiments, ice slurry ingestion caused a more rapid decrease in core temperature than did peripheral cooling, with little decrease in peripheral temperatures and little peripheral cold discomfort. In contrast, exposure to 7°C air caused a much slower decrease in core temperature, with no significant decrease after 40 minutes of exposure, but much greater decreases in peripheral temperatures, peripheral temperature perceptions, and peripheral comfort perceptions (Figure 6a-e). Theoretically, the ice slurry ingestion should have caused the greatest reduction in central nerve conduction velocities resulting in greater evoked potential latencies, while causing the least arousal and distraction. Conversely, exposure to 7°C air should have had a lesser effect on central EP latencies and a greater effect on arousal and distraction.

The above hypothesis is supported by the data presented here. The faster reaction times after 30 minutes of 7°C air exposure (Figure 8) when rectal temperatures had not fallen significantly support Enander's (4) hypothesis, which suggested decreases in reaction time during cold exposure could be the result of increased arousal. The mechanism of this decrease in reaction time, whether arousal or some other cause, appears to involve an increase in central conduction velocity in visual pathways, as reflected in the observed decrease in VEP latency (Figure 14). These decreased reaction times resulting from increased conduction velocities would be offset by any decrease in core temperature. In the 80 minute 7°C air sample, this improvement may have been offset by decreased peripheral conduction velocity as indicated by the increased SEP latencies. Van Orden et al. (13) suggested that these offsetting effects may be the cause of the reported discrepancies in the literature.

In contrast to cold air exposure, core cooling from ice slurry ingestion did not result in improvements in reaction time performance (Figure 8) but did cause significantly greater latencies in several AEP parameters, and insignificant increases in VEP and SEP latencies (Figures 9-14). Without an irritating cold stimulus to the skin, the core temperature was decreased and arousal levels were not increased. SEP latencies did not increase significantly because peripheral nerves were not substantially cooled, and VEP latencies increased marginally ($p = 0.098$) due to slowing of central nerve conduction velocity at the first

measurement rather than decreasing from increased arousal as they did during 7°C air exposure.

In summary, these results support the hypothesis of Van Orden et al. (13) that the reaction times recorded in studies employing substantial cooling may have been affected by the slowing of nerve conduction, which would offset increased arousal, thus blunting the decreases in response times that arousal alone would have caused.

Application and future areas of interest generated by Phase I and Phase II results:

Several practical applications of these findings are apparent for both cold stress and heat stress conditions. The initial objective of this research was to determine the mechanisms by which cold exposure causes a decrement in measurable psychomotor performance variables but at the same time results in increased reaction speed. Our results indicate that in addition to the well known physical effects of cold on the human body, the irritation of cold exposure increases the state of arousal, initially resulting in faster reactions in the early stages of cold exposure when core temperature has not yet fallen. The unfortunate cost of this increased arousal may be a tendency to make more mistakes in judgment and performance. Although this stimulation could be useful in maintaining alertness and readiness, the decrease in core temperature which will eventually result from continued cold exposure will slow motor function and offset the effects of arousal, resulting in poorer and slower performance. An optimum performance level for most tasks requiring attention occurs when subjects are not over or under aroused and have a steady but slightly elevated core temperature (5). Perhaps arousal and temperature levels could be manipulated in some special situations to provide optimization of the type of performance required.

An additional point worth noting is the observation that peripheral cooling, like central cooling, showed an effect on nerve conduction as SEP latencies increased. The combined effect of the reduction in muscular strength associated with peripheral cooling, along with the reduced peripheral nerve conduction velocity could markedly compromise psychomotor performance. In light of these findings, maintenance of peripheral body temperature should be considered along with core temperature protection for optimization of performance.

Although the intent of this study was to determine the mechanism of the effects of a cold environment on psychological and psychomotor tasks, several aspects of this data could be useful in heat stress applications. The use of ice slurry ingestion for reduction of core temperature could be more extensively utilized in heat stress conditions. Typically, individuals under heat stress will need to ingest large quantities of liquids to offset perspiration losses. Ingestion of ice slurry rather than liquids provides substantially more cooling effect while maintaining adequate hydration levels. By consuming ice slurry and melting the ice internally,

the latent heat of fusion of ice (80 calories/gram) is absorbed from the body. The data from this study indicates that the cooling effect resulting from this phase change along with the 37 calories/gram required to raise the melted ice from 0°C to body temperature will result in substantial reduction in core temperature in resting subjects, and could be utilized to reduce the core temperature rise in heat stress situations, while providing necessary liquid replacement.

Another area of concern is more directly addressed by the preceding results. In relation to the recent surge of interest in artificial cooling, especially microclimate cooling (15,12,1,7), the effects of different types of cooling (e.g.. internal vs. external) on cognitive and motor performance is not well understood. As our results have demonstrated, all cooling strategies will not have the same effects on physiological and psychological performance. Therefore, the differing effects of internal and external cooling on core temperature, cognitive performance, and psychomotor function should be considered when applying artificial cooling.

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Appendix I: Consent Form

Project title: Studies of Neural and Cognitive Function in Subjects Exposed to the Cold Marine-Air Interface

Investigators: L. E. Wittmers and R. G. Hoffman

Consent Form

You are invited to participate in a study evaluating the effects of various stressful situations associated with a cold environment on human physiological and psychological performance. All studies will take place in the environmental chamber at the Hypothermia Laboratory - University of Minnesota Duluth School of Medicine, Duluth, MN 55812. The project is under the direction of Drs. L. Wittmers and R. G. Hoffman.

In order to participate in this project you will be prescreened to determine if you are physically fit and whether or not you fit the body composition criteria necessary to participate. We will require a short medical history and a 12 lead resting electrocardiogram, interpreted by the staff of the Clinical Science Department. To determine your body composition you will be asked to sit on a chair in a warm swimming pool and immerse your entire body including your head for 10-20 seconds at a time so that we may determine your weight underwater. From this underwater weight, your height, weight, and vital capacity we will calculate your percent body fat. Vital capacity is the volume of your lungs, and we will measure this by having you breath into a machine that will measure how much air you can exhale. If the electrocardiogram is normal and your body fat is 20% or less you will be given a stress test. This will include walking (3 mph) on a treadmill with the grade increased at the rate of 2% up to a maximum of 18%. You will be considered as a candidate for participation if your heart rate does not exceed 90% of the predicted maximum (for your age and sex) and your systolic blood pressure does not exceed 200 mm. Hg. and diastolic blood pressure does not exceed 100 mm. Hg. at 18% grade. You will not be allowed to participate in these experiments if you are taking prescription or non-prescription medications.

If you pass the prescreening above, you will be requested to participate in one or more of the following five experimental situations, each lasting no longer than 3 hours.

(1) Room temperature air. You will be exposed to an air temperature of 72°F for 3 hours.
(2) Moderately cold air: You will be exposed to an air temperature of 45°F for 3 hours.
(3) Cold air. You will be exposed to an air temperature of 20° F for 3 hours.
(4) Warm air/internal cooling: You will be exposed to an air temperature of 80°F for 3 hours. During this time you will be required to drink between 1 and 2 liters (actual amount based on body weight) of flavored ice slurry at a comfortable rate.
(5) Warm air: You will be exposed to an air temperature of 80°F for 3 hours.

These protocols are designed to address the following questions (a) which of the various environmental-stress scenarios is the one that causes the greatest rate of rectal temperature fall and the earliest onset of shivering, and (b) what is the effect of reduction in core temperature and skin temperature on nervous system function.

Following is a description of procedures that will be followed for each experiment. None of these procedures is harmful or dangerous, however, some may cause some mild discomfort, and others are difficult to understand without a demonstration. If you have any questions please feel free to ask for a demonstration before you decide to volunteer for these tests.

During the experiment you will be asked to perform certain mental and physical tasks to evaluate performance. Each task and its meaning will be explained to you by one of the project directors. In order to monitor physiological changes you will be instrumented with temperature sensors (rectal thermocouple, tympanic thermocouple, and seven skin surface thermocouple probes - on your right arm, chest, thigh, calf, face, toe and finger). Surface doppler probes will be applied at intervals to measure blood flow. Electromyographic electrodes will be applied over selected skeletal muscle groups to evaluate shivering, and impedance cardiography electrodes will be attached to your skin to measure the output of your heart. Evoked potential electrodes will be placed on your head and legs to

monitor the function of your nervous system during cold exposure. These electrodes are held on your head by a water soluble electrode paste that rinses off with warm water and on your legs with adhesive tape. Electrode locations will be prepared before application by moderate abrasion with a pumice prep solution. This abrasion will not cause bleeding or permanent injury, however, some temporary redness of the skin may result. During the experiments one of the investigators will apply and electrical stimulus to your ankle which will produce a signal in a nerve. The rate that this signal travels to your brain will be recorded from the electrodes. The electrical stimulus causes a tingling sensation in the ankle but involves little or no pain and no damage to you whatsoever. At intervals you will be required to breathe into a mouthpiece for measurements of how much oxygen you consume and how much carbon dioxide you produce. On the day prior to the experiments you will be asked to drink nine-16 oz. glasses of water (approximately one every 2 hours) in order to insure that you are adequately hydrated. You may be required to give a saliva and urine specimen before and after completion of each experiment and a blood sample after each experiment. The urine samples will be analyzed for catecholamines to assess your individual response to cold stress, and the saliva and blood will be analyzed for substances which indicate the intensity of muscle activity and cold stress. The total amount of the blood sample, if taken, will be less than 50 ml (1.7 oz.) per experiment. Blood samples will be drawn and analyzed at a local medical facility approximately 24 hours after completion of each test. A minimum of 72 hours will elapse between each experiment.

You will be paid $100 for each experimental condition.

From our experience we expect that the protocols described above will cause moderate discomfort, especially of the hands and feet. Exposure to cold will result in an increase in heart rate and blood pressure. There are potential risks of abnormal heart beats, however at the temperatures you will be exposed to these are extremely rare. You will be continuously monitored to allow us to minimize any risk. Cold exposure can cause tissue damage by freezing. You will have sufficient protective clothing to avert this tissue damage and your rectal and skin temperatures will be continuously monitored. There may be some mild discomfort in placing the rectal thermistor and having it in place while participating in the experiment. If you have any problems, please notify one of the project directors immediately.

Safety assurance is the responsibility of the project directors. There will be a physician on call in the building during the entire exposure period in the event of a medical injury.

Any subject can terminate his/her involvement at any time without affecting their relationship with the University of Minnesota, Duluth or the U. S. Navy (the agency supporting this program). The benefits to be expected will be that we will gain more insight into how these cold-stress environments alter human physiological and psychological functioning.

Any information obtained in connection with this study that can be identified with you will remain confidential and will be disclosed only with your permission. In any written reports or publications, no one will be identified or identifiable and only aggregate data will be presented. A representative of the U. S. Navy may inspect the records of this research but confidentiality will be preserved.

Your decision whether or not to participate will not affect your future relations with the University of Minnesota, Duluth School of Medicine or the U. S. Navy in any way. If you decide to participate you are free to discontinue participation at any time without affecting such relationships.

You are authorized all necessary medical care for injury or disease which is the proximate result of your participation in this research. (If you receive an injury or contract a disease as a direct result of your participation in this project all medical expenses will be the responsibility of the research project.)

If you have questions about the research, please call Dr. L. E. Wittmers, 726-8551 or the other project director. If you have questions about the research subjects' rights or wish to report a research-related injury please call Dr. Ronald Franks, Dean, University of Minnesota, Duluth School of Medicine, Duluth, MN, 55812 (218-726-7571).

You will be offered a copy of this form to keep.

You are making a decision whether or not to participate. Your signature indicates that you have read the information provided above and have decided to participate. You may withdraw at any time without prejudice after signing this form.

Signature Date

Signature of Witness Signature of Investigator

Appendix I. Subject Data

Subject #	Weight (kg)	Age	% Body Fat
1	58.6	27	8.5
2	80.9	23	16.3
3	80	29	11.5
4	83.9	29	21.1
5	88.6	22	14.5
6	79.8	29	11.7
7	80.4	24	13.7
8	77.3	24	20.5
9	78.6	24	13.1
10	64.1	21	12.9
11	*	23	*
Mean	79	25.00	15
Std. Dev.	8.2	2.97	4.1

* data missing

Appendix II. Temperature Data for Individual Subjects.

Rectal (°C)	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1				37.8	37.6	37.2
2	37.3	36.5	36.6	37.1	37.0	
3	38.1	36.7	36.7	37.9	37.5	
4	37.9	37.1	36.7	37.7	37.4	37.0
5	37.1		36.7	38.0	37.6	37.5
6	37.3	36.6	36.9			
7	37.5	37.0	37.2	37.6	37.8	37.9
8	37.4	36.7	36.8	37.2	37.3	36.6
9	37.6	36.5	36.6	37.7	37.3	36.8
10	37 7			37.5	37.2	
11	37.3	36.6	36.9	36.7	37.1	37.1

Tympanic (C)	Ice Slurry Ingestion			7 C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1				36.8	36.3	36.3
2	36.1	35.6	35.0	36.4	36.3	
3	36.4	35.2	35.7	36.7	36.0	
4	36.3	35.4	35.2	36.4	34.7	
5	36.3		35.3	36.5	35.3	34.7
6	36.6		29.4			
7	37.0	36.3	36.6	37.1	35.4	35.4
8	36.5	35.2	36.0	36.1	35.4	35.4
9	36.1	34.9	35.6	36.4	35.3	34.5
10	36.8			36.6	35.3	
11	36.5	35.6	36.0	35.6	36.2	36.1

Mean Skin (C)	Ice Slurry Ingestion			7 C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1				33.4	27.3	28.2
2	34.7	34.7	34.9	33.9	30.9	
3	33.3	33.2	33.3	33.8	29.2	
4	33.9	33.5	33.2			
5	33.7		34.1	33.9	30.3	28.8
6						
7	34.4	34.5	35.2			
8	34.3	33.6	34.2	34.1	31.4	30.6
9	34.1	33.4	33.5	33.9	30.9	28.2
10	34.9			33.8	29.9	
11	33.8	33.5	33.5	33.7	28.6	28.9

Finger (C)	Ice Slurry Ingestion			7 C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1				33.8	16.7	18.0
2	36.5	29.8	32.7	35.3	27.6	
3	35.5	26.6	27.3	33.0	21.4	
4	34.6	28.9	26.4	36.6	14.3	27.8
5	34.8		27.1	34.5	14.5	19.0
6	34.8	28.3	28.4			
7	36.8	29.5	31.6	36.2	21.3	21.7
8	36.2	27.3	30.5	35.7	21.0	29.8
9	33.1	24.8	28.6	30.0	19.8	24.2
10	36.1			35.7	26.4	
11	35.6	29.7	30.8	35.7	24.6	23.1

Toe (C)	Ice Slurry Ingestion			7 C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1				26.7	17.2	14.1
2	34.6	33.5	32.8	32.2	25.9	
3	28.5	25.8	25.8	22.2	11.1	
4	27.8	27.2	25.9	35.4	21.0	16.9
5	30.3		26.6	25.8	16.9	13.9
6	26.6	25.4	27.6			
7	33.8	29.1	32.6	33.6	16.5	15.2
8	35.3	29.3	28.1	31.4	17.8	13.3
9	28.1	25.2	24.8	24.3	19.4	16.2
10	35.3			31.2	22.6	
11	34.3	29.9	28.5	29.6	25.1	22.0

Appendix III. Comfort and Temperature Perception Data for Individual Subjects.

7°C Air Condition		Comfort Perception (mm)				Temperature Perception (mm)		
Subject #	Sample	Fingers	Toes	Body		Fingers	Toes	Body
1	control	96	95	95		96	97	96
2	control	92	94	95		96	95	95
3	control	99	99	99		98	98	99
4	control	99	99	100		99	99	100
5	control	100	100	100		100	100	100
6	control	95	96	94		*	*	*
7	control	87	88	86		70	66	69
8	control	98	100	100		99	99	100
9	control	99	99	98		98	97	98
10	control	97	96	98		97	98	96
11	control	100	100	100		100	100	100
1	40 min.	58	53	51		42	42	41
2	40 min.	90	85	63		90	86	57
3	40 min.	97	94	77		89	87	62
4	40 min.	97	95	91		97	99	88
5	40 min.	87	78	89		76	62	83
6	40 min.	61	48	39		*	*	*
7	40 min.	48	38	27		55	31	29
8	40 min.	51	17	66		68	27	49
9	40 min.	81	72	66		61	68	60
10	40 min.	29	26	27		8	8	
11	40 min.	98	80	51		98	76	55
1	80 min.	44	28	32		40	32	40
2	80 min.	49	33	45		31	16	23
3	80 min.	31	50	41		34	50	50
4	80 min.	85	83	78		92	94	95
5	80 min.	47	39	54		41	34	47
6	80 min.	81	30	60		62	26	71
7	80 min.	*	*	*		*	*	*
8	80 min.	79	12	33		89	5	25
9	80 min.	*	*	*		*	*	*
10	80 min.	76	63	64		64	37	61
11	80 min.	61	43	47		36	27	10

Ice Slurry Condition		Comfort Perception				Temperature Perception		
Subject #	Sample	Fingers	Toes	Body		Fingers	Toes	Body
1	control	97	97	97		97	97	96
2	control	100	100	100		100	100	100
3	control	97	98	99		98	97	97
4	control	100	100	100		100	9[illegible]	100
5	control	100	100	100		100	100	100
6	control	95	96	89		88	89	98
7	control	85	79	85		82	85	84
8	control	99	99	99		92	83	77
9	control	95	97	98		96	98	95
10	control	95	97	96		99	98	98
11	control	99	99	99		99	100	100
1	40 min.	94	96	71		92	91	61
2	40 min.	*	*	*		*	*	*
3	40 min.	98	98	78		97	97	68
4	40 min.	98	98	98		98	99	91
5	40 min.	*	*	*		95	97	73
6	40 min.	81	79	60		91	67	63
7	40 min.	78	49	74		85	85	33
8	40 min.	85	97	68		99	86	63
9	40 min.	97	96	29		96	98	26
10	40 min.	69	93	57		89	67	61
11	40 min.	100	100	77		100	99	74
1	80 min.	93	90	65		96	95	65
2	80 min.	100	100	99		100	99	100
3	80 min.	98	98	66		97	97	63
4	80 min.	97	92	63		99	99	64
5	80 min.	*	*	*		*	*	*
6	80 min.	85	85	88		71	70	63
7	80 min.	77	80	81		81	73	74
8	80 min.	90	89	91		83	83	87
9	80 min.	89	95	49		95	95	56
10	80 min.	*	*	*		*	*	*
11	80 min.	100	99	75		100	100	77

* Data missing

Appendix IV. Reaction Time Data for Individual Subjects (all values expressed in seconds).

	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	0.29	0.28	0.26	0.25	0.22	0.21
2	0.29		0.31	0.31	0.23	0.26
3	0.28	0.34	0.27	0.26	0.29	0.35
4	0.29	0.32	0.32	0.33	0.30	0.32
5	*	*	*	0.28	0.26	0.28
6	*	*	*	*	*	*
7	0.34	0.31	0.28	*	*	*
8	0.30	0.36	0.38	0.30	0.27	0.31
9	*	*	*	0.33	*	0.31
10	0.27	0.26	*	0.27	0.23	0.28
11	0.34	0.31	0.28	0.33	0.32	0.42

* Data missing due to technical difficulties

Appendix V. Evoked Potential Data for Individual Subjects (all latencies expressed in msecs.).

AEP Peak I	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	1.80	1.76	0.98	1.64	1.08	0.78
2	1.96	1.84	1.90	1.05	2.11	*
3	1.80	1.90	1.94	1.86	*	*
4	1.84	1.70	1.74	1.68	1.70	1.66
5	*	*	*	1.96	2.36	1.84
6	*	1.78	1.02	1.58	1.34	1.34
7	1.92	1.86	1.90	1.92	2.10	*
8	1.88	1.90	1.80	2.04	2.00	*
9	1.82	1.22	1.96	1.82	*	1.94
10	1.90	*	*	1.90	1.88	*
11	1.56	*	1.82	1.84	1.84	1.76

AEP Peak III	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	4.02	4.24	3.54	4.24	4.12	4.10
2	3.92	4.00	3.92	3.04	3.99	*
3	4.03	4.02	4.12	4.04	3.90	*
4	4.00	4.06	4.04	3.98	3.80	3.94
5	4.20	*	*	4.30	4.40	4.22
6	*	3.86	4.18	3.74	4.46	3.96
7	4.08	4.08	4.08	4.08	*	*
8	3.98	4.02	4.08	4.08	4.12	*
9	4.12	3.22	4.06	3.98	4.24	4.06
10	4.02	*	*	4.38	4.00	*
11	3.68	4.02	4.02	4.00	3.94	3.90

AEP Peak V	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	6.08	6.74	6.14	6.26	6.18	5.98
2	5.78	5.86	5.98	5.25	5.83	*
3	5.93	6.12	6.16	5.74	5.86	*
4	5.98	6.10	6.02	5.96	5.86	6.10
5	*	*	*	6.18	5.88	5.84
6	*	5.74	6.10	5.62	*	5.68
7	5.76	5.88	6.08	6.06	6.42	*
8	6.02	6.24	6.08	6.02	6.14	*
9	6.06	5.68	6.12	5.94	6.12	6.16
10	5.72	*	*	6.48	6.12	*
11	5.50	5.92	5.78	5.86	5.70	5.78

* Data inappropriate for analysis due to artifact from shivering or technical difficulties.

AEP Peak I-III	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	2.22	2.48	2.56	2.60	3.04	3.32
2	1.96	2.16	2.02	1.99	1.88	*
3	2.95	2.12	2.18	2.18	*	*
4	2.16	2.36	2.30	2.30	2.10	2.28
5	*	*	*	2.34	2.04	2.38
6	*	2.08	3.16	2.16	3.12	2.62
7	2.14	2.22	2.18	2.16	3.04	*
8	2.10	2.12	2.28	2.04	2.12	*
9	2.30	2.00	2.10	2.16		2.12
10	2.12	*	*	2.48	2.12	*
11	2.12	*	2.20	2.16	2.10	2.14

AEP Peak III-V	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	2.06	2.50	2.60	2.02	2.06	1.88
2	1.86	1.86	2.06	2.21	1.84	*
3	1.90	2.10	2.04	1.70	1.96	*
4	1.98	2.04	1.98	1.98	2.06	2.16
5	*	*	*	1.88	1.48	1.62
6	*	1.88	1.92	1.88	2.78	1.72
7	1.70	1.80	2.00	1.98	1.28	*
8	2.04	2.22	2.00	1.94	2.02	*
9	1.94	2.46	2.06	1.96	1.88	2.10
10	1.70	*	*	2.10	2.12	*
11	1.82	1.90	1.76	1.86	1.76	1.88

AEP Peak I-V	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	4.28	4.98	5.16	4.62	5.10	5.20
2	3.82	4.02	4.08	4.20	3.72	*
3	4.13	4.22	4.22	3.88	*	*
4	4.14	4.40	4.28	4.28	4.16	4.44
5	*	*	*	4.22	3.52	4.00
6	*	3.96	5.08	4.04	5.90	4.34
7	3.84	4.02	4.18	4.14	4.32	*
8	4.14	4.34	4.28	3.98	4.14	*
9	4.24	4.46	4.16	4.12	3.98	4.22
10	3.82	*	*	4.58	4.24	*
11	3.94	*	3.96	4.02	3.86	4.02

* Data inappropriate for analysis due to artifact from shivering or technical difficulties.

SEP Peak N45		Ice Slurry Ingestion		7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	42.00	42.40	*	42.00	43.20	44.40
2	41.20	41.60	41.20	40.80	41.80	42.00
3	*	47.60	54.40	55.00	44.80	*
4	43.20	42.80	42.60	44.20	*	44.80
5	44.80	45.60	*	42.80	43.60	46.80
6	44.40	45.20	44.00	53.20	53.40	56.60
7	39.80	41.40	41.40	49.00	49.20	49.60
8	44.60	46.00	46.00	45.40	45.00	47.00
9	47.00	60.40	58.80	43.40	43.00	44.80
10	40.40	41.80	*	40.20	41.00	41.80
11	40.00	40.08	41.20	43.00	44.00	44.00

SEP Peak P37		Ice Slurry Ingestion		7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	36.50	36.50	*	30.60	34.80	39.40
2	34.20	34.60	34.80	34.60	34.80	36.50
3	*	39.20	37.20	38.00	39.00	*
4	35.20	37.00	36.40	36.20	*	36.40
5	35.40	37.60	*	36.00	36.00	38.00
6	38.20	38.60	38.20	44.00	44.80	47.60
7	30.80	30.80	31.60	41.00	36.00	*
8	34.40	35.80	35.00	34.80	35.60	36.80
9	37.60	48.40	47.00	34.00	35.20	36.00
10	33.60	34.80	*	33.80	34.40	35.40
11	30.20	35.20	33.80	32.80	34.80	37.20

SEP Peak N21		Ice Slurry Ingestion		7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	*	*	*	*	*	*
2	*	*	*	23.80	23.00	*
3	*	26.40	25.60	23.90	20.00	*
4	23.40	23.20	24.00	20.80	20.80	22.40
5	*	*	*	23.20	*	*
6	*	*	*	*	*	*
7	22.00	22.40	21.80	*	*	*
8	21.20	21.80	22.00	21.00	21.40	22.40
9	26.60	23.60	22.80	*	*	*
10	21.00	22.80	*	21.40	19.40	24.20
11	23.40	25.00	23.60	25.80	26.00	*

* Data inappropriate for analysis due to artifact from shivering or technical difficulties.

SEP Peak PF — Ice Slurry Ingestion / 7°C Air Exposure

Subject #	Ice Slurry Ingestion Control	40 min.	80 min.	7°C Air Exposure Control	40 min.	80 min.
1	9.50	*	*	9.60	*	*
2	8.20	8.20	8.20	7.60	8.60	9.00
3	*	10.80	10.80	11.20	11.80	*
4	8.20	8.40	8.40	7.60	8.40	9.20
5	*	10.00	*	8.20	9.00	10.00
6	9.60	10.00	9.40	10.00	*	*
7	8.20	8.40	8.00	7.20	10.40	*
8	7.00	7.60	7.50	7.20	8.20	8.80
9	11.20	12.80	11.60	8.80	9.20	10.80
10	9.00	9.40	*	6.60	7.20	7.60
11	7.20	10.40	7.60	9.20	10.00	10.60

SEP N21-P37 — Ice Slurry Ingestion / 7°C Air Exposure

Subject #	Ice Slurry Ingestion Control	40 min.	80 min.	7°C Air Exposure Control	40 min.	80 min.
1	*	*	*	*	*	*
2	*	*	*	11.80	11.80	17.80
3	*	12.80	11.60	14.10	19.00	*
4	11.80	13.80	12.40	15.40	15.60	14.00
5	*	*	*	12.80	*	*
6	*	*	*	*	*	*
7	8.80	8.40	9.80	*	*	*
8	13.20	14.00	12.00	13.80	14.20	14.40
9	9.00	24.80	24.20	*	*	*
10	12.60	12.00	*	12.40	15.00	11.20
11	6.80	10.20	10.20	7.00	8.80	*

SEP PF-N21 — Ice Slurry Ingestion / 7°C Air Exposure

Subject #	Ice Slurry Ingestion Control	40 min.	80 min.	7°C Air Exposure Control	40 min.	80 min.
1						
2	*	*	*	15.20	14.40	15.40
3	*	15.60	14.80	12.70	8.20	*
4	15.20	14.80	15.60	13.20	12.40	13.20
5	*	*	*	15.00	*	*
6	*	*	*	*	*	*
7	14.20	14.00	13.80	*	*	*
8	14.20	14.20	14.50	13.80	13.20	13.60
9	17.40	10.80	11.20	*	*	*
10	12.00	13.40	*	14.80	12.20	16.60
11	16.20	14.60	16.00	16.60	16.00	*

* Data inappropriate for analysis due to artifact from shivering or technical difficulties.

VEP Peak N75	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	69.00	*	*	71.00	74.00	73.00
2	69.00	74.00	68.00	64.00	*	69.00
3	69.00	69.00	69.00	72.50	72.00	*
4	*	82.00	76.00	71.00	69.00	74.00
5	71.00	84.00	76.00	73.00	78.00	75.00
6	66.00	74.00	77.00	74.00	*	*
7	77.00	77.00	76.00	82.00	80.00	*
8	65.00	74.00	67.00	68.00	79.00	80.00
9	81.00	80.00	72.00	75.00	70.00	69.00
10	78.00	73.00	*	61.00	71.00	73.00
11	73.00	76.00	72.00	*	62.00	67.00

VEP Peak P100	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	98.00	106.00	*	106.00	103.00	107.00
2	103.00	102.00	100.00	94.00	*	101.00
3	105.00	112.00	101.00	103.00	99.00	*
4	112.00	104.00	100.00	99.00	92.00	98.00
5	99.00	106.00	100.00	101.00	102.00	101.00
6	93.00	94.00	97.00	104.00	*	*
7	108.00	110.00	109.00	115.00	108.00	*
8	102.00	105.00	101.00	103.00	97.00	101.00
9	104.00	106.00	99.00	101.00	96.00	99.00
10	102.00	98.00	*	107.00	95.00	96.00
11	93.00	96.00	98.00	99.00	97.00	92.00

VEP Peak N145	Ice Slurry Ingestion			7°C Air Exposure		
Subject #	Control	40 min.	80 min.	Control	40 min.	80 min.
1	139.00	*	*	135.00	128.00	132.00
2	139.00	141.00	135.00	132.00	*	127.00
3	156.00	173.00	165.00	162.50	161.00	*
4	150.00	137.00	130.00	129.00	120.00	132.00
5	151.00	159.00	141.00	144.00	154.00	131.00
6	*	*	176.00	*	*	*
7	*	*	*	143.00	154.00	*
8	127.00	130.00	133.00	128.00	120.00	130.00
9	127.00	133.00	125.00	125.00	130.00	126.00
10	140.00	150.00	*	125.00	120.00	117.00
11	125.00	127.00	123.00	137.00	127.00	120.00

* Data inappropriate for analysis due to artifact from shivering or technical difficulties.